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No. 31

SEARCH LIGHTS

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PREFACE

This article is intended to present the subject of searchlights from the operator's standpoint. The first three chapters deal with their details and the others their operation.

Figs. 2, 6, 8, and 15 are from Anderson's Handbook, through the courtesy of the author, Lieut-Colonel G. L. Anderson, C.A.C. Frontispieces, Figs. 5, 6, 13, 14, 15, 16, 17, 18, 40, 41 and 42 are from photographs furnished through the kindness of the General Electric Company. The other photographs were taken for the writer at Fort Totten by Master Electrician, C. M. Beers, C.A.C. Figs. 3, 18, 24, 25, 38, 43, 44 and 45 and those in the appendix are made from General Electric Company drawings.

Among the publications on searchlights consulted are:—

(1) Anderson's Handbook.

(2) Light Projectors for Army and Navy by F. Nerz. (Translation with notes by Captain E. H. Schulz, Corps of Engineers.)

(3) Remarks on Searchlight Projectors for Coast Defense Service, by Lieutenant Waldron, Corps of Engineers, and Mr. J. L. Hall of the General Electric Company.

(4) Instruction Book No. 8189 on Searchlight Projectors, by the General Electric Company.

Information obtained elsewhere has come chiefly from various Artillery officers.

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Boston, Mass.

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60-INCH PROJECTOR AND CONTROLLER.

CHAPTER I.

PARTS, CONSTRUCTION, ETC.

The principal parts of a searchlight are the lamp, reflector, drum, lamp box, glass front door, standards, turntable, pedestal and training mechanism.*

The lamp is for producing the light, and consists chiefly of a pair of carbons, and a starting and feeding mechanism to form and maintain the arc. The crater faces the reflection and is kept in its focus, after first adjustment, by the feeding mechanism.

The reflector is a parabolic mirror and it projects the light in a beam whose rays are sensibly parallel. The drum and lamp box are together a casing for the lamp and reflector. The lamp rests on guides fastened to the lamp box and may be moved forward or backward by turning the focussing screw, the head of which may be seen at O, Fig. 16, and this screw engages in a nut M, Fig. 2, fastened to the lamp frame. The glass front door is for protection to the lamp and mirror. The drum is pivoted on trunnions that bear on standards which are bolted to the turntable. The turntable rests on rollers on top of the pedestal, see Fig. 21.

The drum, and consequently the beam, may be given a vertical motion on the trunnions, or a horizontal motion on the rollers, or both simultaneously, such being necessary for training the beam. The training normally is by means of an electric control mechanism. But there is an auxiliary mechanism so that, in case the electric control fails, the training may be done at the projector by hand.

The electric control mechanism consists of two training motors, located in the pedestal and connected electrically with the controller in such a manner that both may be operated with varying speeds in either direction. One, the vertical training motor, through a gear train transmits a vertical motion to the beam, and the other, the horizontal training motor through a gear train drives a pinion which engages with a pinion on the turntable giving

* In this article all references to searchlights bear only on those used in the U. S. Coast Artillery unless otherwise stated. It may be remarked that the terms "projector" and "searchlight" mean practically the same thing. The manufacturers in general apply the word "projector", while in the Coast Artillery Drill Regulations the usage is "searchlight."

the horizontal motion; the beam being trained at will by simply moving the handle of the controller which is usually located at a distance from the projector.

CLASSIFICATION OF SEARCHLIGHTS

As to size, searchlights are classified according to the diameters of their reflectors. Below is given a table of the different lights made by the General Electric Company*:

Size of Lamp	Normal Current	Normal volt. across arc	Positive carbon	Negative carbon
13-inch	20	45	$\frac{5}{8}''$ x 6″ cored	$\frac{1}{2}''$ x $4\frac{1}{2}''$ solid
18-inch	35	45	$1\frac{3}{8}''$ x $8\frac{1}{2}''$ cored	$\frac{5}{8}''$ x 5″ solid
24-inch	50	48	1″ x 12″ large core	$\frac{3}{4}''$ x 7″ small core
30-inch	80	50	$1\frac{1}{8}''$ x 12″ "	$\frac{7}{8}''$ x 7″ "
36-inch	130	60	$1\frac{1}{4}''$ x 12″ "	1″ x 7″ "
48-inch	160	63	$1\frac{27}{32}''$ x 12″ "	$1\frac{3}{16}''$ x 12″ "
60-inch	200	65	$1\frac{31}{32}''$ x 15″ "	$1\frac{3}{16}''$ x 12″ "
80-inch	250	67	$2\frac{1}{4}''$ x 15″ "	$1\frac{3}{4}''$ x 12″ "

Up to date the sizes that have been installed are the 24, 30, 36 and 60 inch. The present practice is to have two sizes only, one for the long ranges, and the other for the medium ranges, the adopted sizes being the 60 and 36 inch. Perhaps the 48 and 80 inch together may give a better combination of ranges; however it is a question whether the increase in cost would be justified by the small amount of gain in range.

As to their use in the fire control system, searchlights are classified as searching and illuminating lights. Searching lights cover or search all avenues of approach in a harbor so that any vessel may be discovered and identified. Illuminating lights are used after discovery and identification by the searching lights, to follow the vessels so as to make them visible to the necessary observers in the fire control system. For further details see Drill Regulations.

As to construction, there are two classes of searchlights. The essential difference occurs in their method of electric control, one having a long distance and the other a short distance method. In practice they are distinguished by calling one the "old" and the "new" searchlight, the latter having the long distance method of control. On account of loss in cable 150 feet is the maximum distance of control for the old, while satisfactory results may be obtained for several thousand feet with the new

* All searchlights used by the U. S. Coast Artillery with one or two exceptions are manufactured by the General Electric Company.

light. The new light has only been installed during the past year or two.

THE ARC

To form an arc two electrodes in circuit with a sufficient source of electro-motive force must be brought together and separated. After coming in contact and while being separated there comes a point at which the resistance of the touching electrodes is such that the current starts the tips burning, and this burning sets up a stream of conducting material that runs between them: it has a fairly low resistance and may be drawn to certain lengths and there maintained. The starting of the initial burning is promoted, no doubt, by the additional electro-motive force brought into the circuit by the collapse of the current field just when the carbon tips are separated.

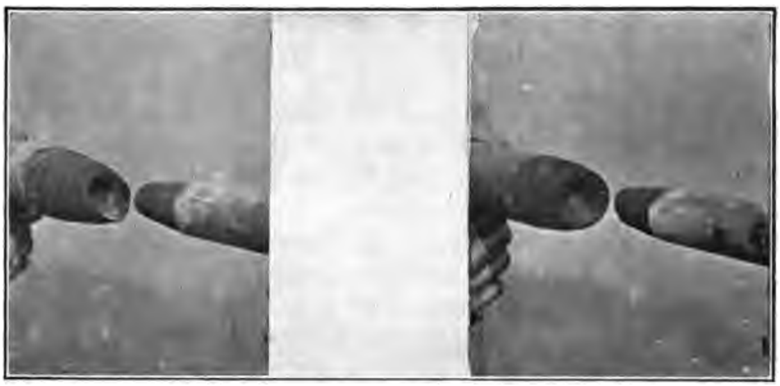

Fig. 1. Carbons showing uneven and even formations of the crater.

An arc can be set up and maintained by either direct or alternating current. Its chief application is as an illuminant and there are several varieties of electrodes used. For searchlight purposes, however, an arc from pure carbon electrodes supplied with direct current is found best and is used entirely.

The effect of the current on the two electrodes is different, the positive takes a cup-like shape while the negative becomes tapered, see Fig. 1. Furthermore, the positive is consumed faster, and for this and other reasons is always made larger. The cup-like depression is called the crater. When the arc is burning the crater has a temperature of boiling carbon, estimated by various authorities from 3500° to 6000° C*; the surface of the crater reaches a

* It is claimed that the temperature of the crater increases with the current. See Waidner and Burgess "On the Temperature of the Arc," Bulletin of the Bureau of Standards for November, 1904.

remarkable incandescence, the highest known, and it is from here that we get our light; the rest of the light from the arc is relatively quite insignificant and is totally lost so far as the beam is concerned, that referred to is from the stream and negative carbon tip.

The light emitted from the crater depends on its incandescent area, and this depends on both the current and the carbons. For good results, therefore, we should have a steady current and carbons of proper quality and dimensions.

The question of current regulation is taken up under the chapter on Power Supply.

As to the carbons, this is a matter of cut-and-try. Though the manufacture of carbons has been well developed on account of the arc's extensive use commercially, we meet more or less difficulty in high currents such as a searchlight demands. It is the writer's belief, however, that carbon troubles are much exaggerated, and that our numerous arc troubles come mostly from poor current regulation and not from anything inherent in the carbons.

The size of the carbons used for the various lamps are given in the table on Page 2. It may be noted that the diameters of the negatives are smaller than those for the positives: this is to gain exposure of the crater to the mirror. The currents given should be closely adhered to, because if the currents exceed these values, bad arc characteristics are likely to develop.

Other electrodes than those of pure carbon have been tried. Though successful for ordinary street lighting lamps, it is claimed they develop serious disadvantages on high currents. The street lamps referred to are the various flaming and luminous arcs. Carbon is, no doubt, the best substance for the electrodes, on account of its high melting point.

The potential* distribution across the arc is about 40 volts between the positive carbon and the stream, a variable value across the stream dependent upon its I R, and about 2½ volts between the stream and negative carbon.

The drops between the positive carbon and stream and the negative carbon and stream are approximately the same for all pure carbon electrodes. The arc's voltage, therefore, is a constant plus a variable, the latter being the I R of the stream.

Though the stream's resistance is proportional to its length, cross-section and temperature, each of these quantities is a function of the current because the rate of generation of the

* See page 300, Crocker's Electric Lighting.

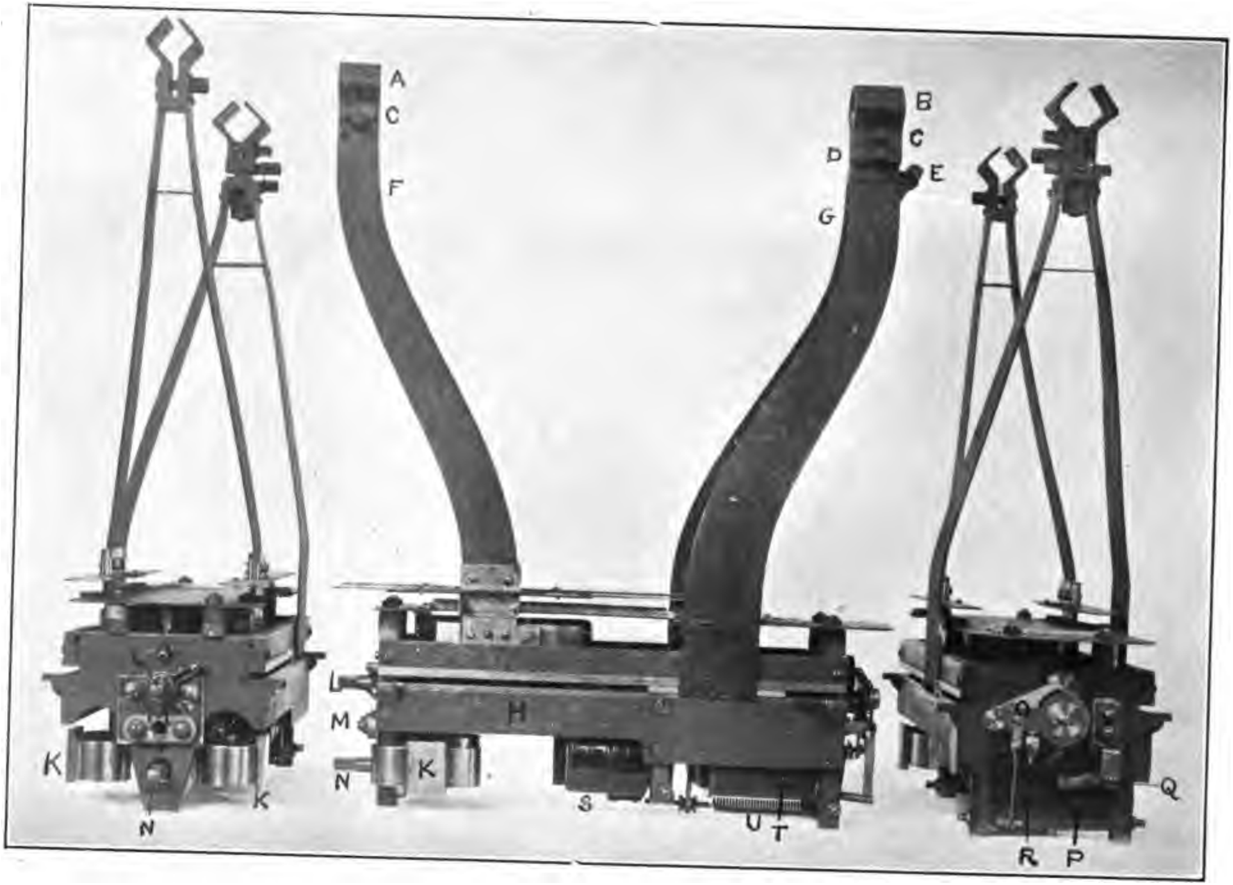

Fig. 2. Parts of Lamp Mechanism.

material for the stream is proportional to the current. It is, therefore, quite indefinite to refer to an arc without stating the current. For searchlight purposes we should state the voltage in addition, for this will convey an idea as to the arc's length because, within certain limits, the length, for a given current, is directly proportional to the voltage.

The stream length is of importance because the greater it is, the less the obstruction to the crater. However, we are restricted here because too much length will develop bad arc characteristics. Such lengths as are suitable for the various currents have been found by trial; those selected by the General Electric Company are given in the table on Page 2. It is well to adhere quite closely to these values.

THE ELECTRIC CIRCUIT AND PARTS OF THE LAMP

The parts of the lamp and the electric circuit are shown in the different figures. Lamps for all sizes of searchlights are essentially the same in construction.

Fig. 2 shows the type of lamp used for the 36-inch and smaller sizes of searchlights. The parts of this lamp's mechanism are given below:

A Negative carbon holder
B Positive carbon holder
C Clamping screws for carbon clamps
D Vertical adjusting screw for positive carbon lamp
E Horizontal ajdusting screw for positive carbon lamp
F Negative carbon support
G Positive carbon support
H Lamp frame
K Main lamp contact shoes
L Hand feed screw
M Fixed nut for focusing screw
N Stud of lamp switch for cutting out feeding magnet
O Ratchet and pawl
P Feeding magnet armature
Q Contact of circuit breaker
R Adjusting screw for ratchet arm
S Starting magnet
T Feeding
U Adjusting spring for feeding magnet

Fig. 5 shows the type of lamp used in the 60-inch and Fig. 6 gives each part and its name.

Current for the lamp is brought to the projector by the cables which enter the pedestal going direct to a snap switch* whose handle is at E, Fig. 16; from there leads are taken to plunger contacts which bear on contact rings attached to insulated wire from the turntable, see Fig. 3; they are then brought through the back of the lamp box and each is connected to a flat copper contact

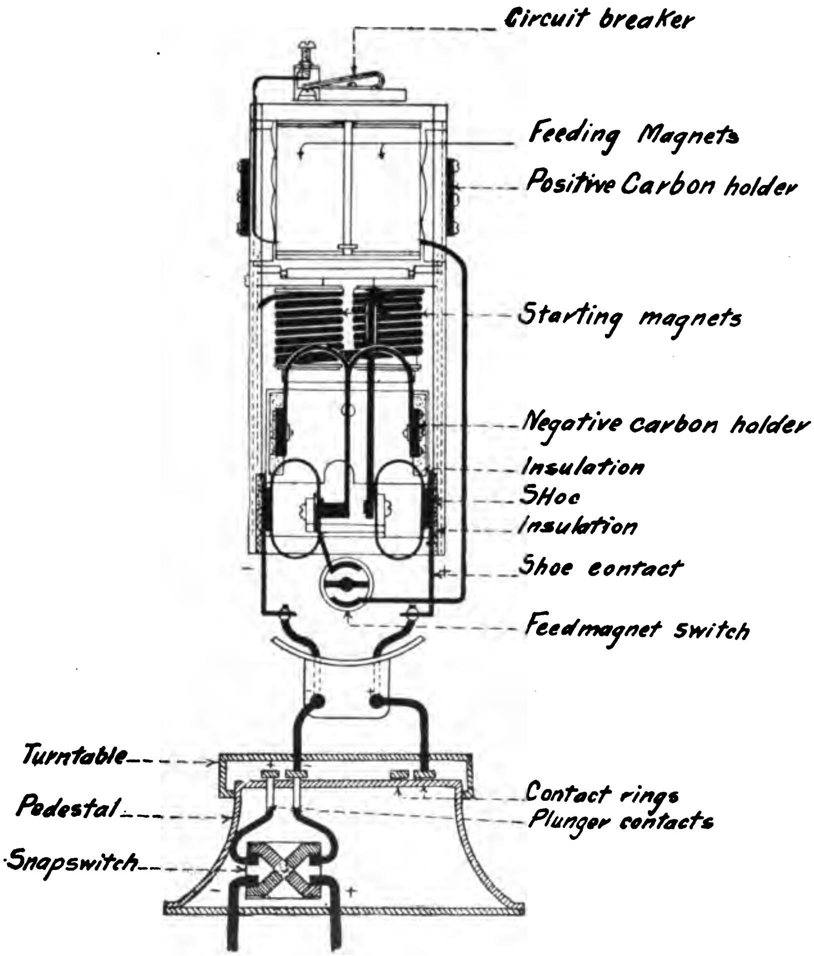

Fig. 3. Diagrammatic sketch of lamp circuits. [Made from drawing of old navy type of hand control projector.]

strip attached to and insulated from the sides of the lamp box and these form contacts respectively for the lamp shoes. In Fig. 3 the lamp is in position in the box shown in plan.

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* Not on 60-inch size.

The lamp circuits are perhaps clearer by looking first at the diagrammatic sketch, Fig. 4, and afterwards locating the actual connections and parts from the other figures. The sketch is based on the construction of a certain 36-inch lamp. There are two circuits, the series circuit which includes the arc and the feed magnet circuit in shunt with it. The series circuit is from positive contact shoe to series magnet, thence to the positive carbon

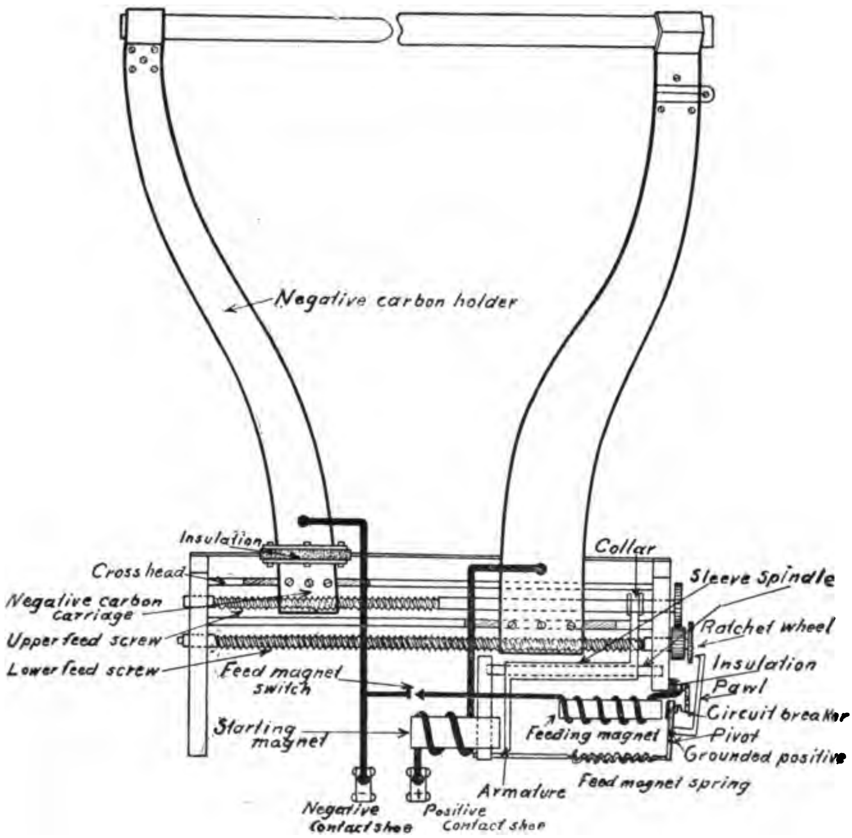


Fig. 4. Diagrammatic sketch of 36-inch lamp circuits. [Some parts are not shown in their proper location.]

holder, to the arc, and then back through the negative carbon holder to the negative contact shoe; after passing through the series magnet the circuit is connected to the frame*, the frame being a part of the circuit. The feed magnet circuit is from the circuit breaker spring (positive) to the other circuit breaker con-

* For the larger sizes the carriages have rollers and the current is not carried by the frame.

tact then to the feed magnet and through switch to the negative line*. The carbon supports rest on carriages which have cross-heads, or rollers, movable in guides.

The feed screws pass through the lamp frame, each having a gear wheel which meshes with the other. These feed screws pass through nuts in the positive and negative carriages, respectively. Fastened to the lower feed screw is a ratchet wheel into which a pawl engages, the pawl being on an arm actuated by the feed magnet armature. The turning of the ratchet wheel, caused by a reciprocating movement of the armature, makes the carbons feed together.

When the arc is not burning the starting magnet armature is held away from its poles by a spring (not shown in Fig. 4). At the starting of the arc the armature is attracted and its motion is transmitted to the negative carbon drawing it back, the distance being the greatest at which the arc may be started reliably from cold carbons. The mechanical transmissions of the motion, in the 36-inch lamp† from which the sketch is made, is as follows: The armature is connected through an arm to a sleeve that moves on a spindle; and the other end of the sleeve has an arm that engages between two collars on the upper feed screw, which has play, hence the negative carbon support may be moved through the required distance, the gear wheel of the lower feed screw being sufficiently wide to allow the movement. If the arc ceases to burn for any cause, the spring brings the magnet from its armature; in which position the mechanism is ready for starting when the current is turned on again.

The latest make of lamp has the feeding mechanism so that the armature has its pivot parallel to the longer axis of the lamp, *i.e.* facing to one side instead of the front. In the present location, when the lamp is moved from a horizontal position, gravity sets up a movement that changes slightly the feeding voltage. This later construction overcomes this difficulty.

THE ACTION OF THE LAMP

In starting the lamp, when the circuit is closed, the resistance in the air gap prevents any current from flowing in the arc circuit and the voltage between the carbons will be practically that of the generator. This difference of potential causes sufficient current

* Some lamps do not have a switch in the feed magnet circuit.

† In some lamps the mechanical transmission of motion from the starting magnet's armature to the negative carbon support is different. See Fig. 6.

Fig. 5. 60-Inch Lamp.

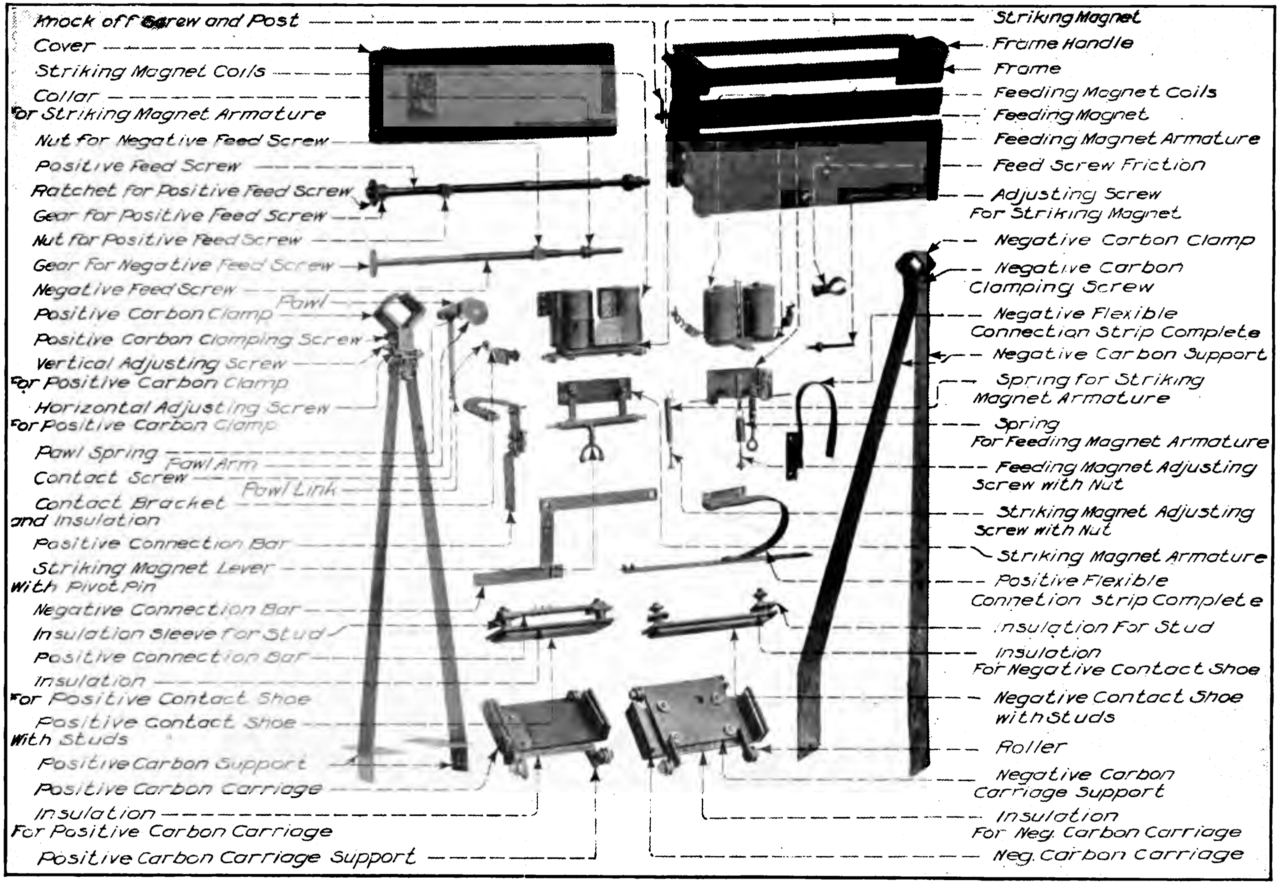


Fig. 6. Parts of 60-Inch Lamp Mechanism.

in the shunt circuit so that the feed magnet attracts its armature and this draws the pawl into the ratchet wheel turning it through a small angle; but the act of drawing the armature breaks the shunt circuit at the circuit breaker contact, and the attraction ceasing the spring returns the armature to its initial position. Since the voltage across the arc remains the same after the first movement, this operation will be repeated and continue until the carbons touch each other, and, when the carbons touch, the large flow of current makes the starting magnet attract its armature, which separates the carbons, forming the arc. After starting, it takes three or four minutes for the crater to burn properly and by that time the carbons are consumed sufficiently to give the arc the proper length. After the arc comes to proper length the feeding mechanism will keep it correct, since it acts whenever the proper voltage is exceeded, provided the spring is properly adjusted and the current is normal.

The action of the feed* mechanism in maintaining the proper length of arc is as follows: The attractive power of the magnet depends upon the current in the feed magnet circuit which is proportional to the difference of potential across the arc and the resistance of the magnet's winding; the latter takes a constant value after the coil gets its normal temperature, hence the feeding is proportional simply to the voltage across the arc; the feed spring is arranged to exert an opposing force to the force of attraction; therefore by giving this spring the proper initial tension, the feeding will take place only above a certain voltage value.

THE OBTURATOR

Fig. 7 gives a picture of an obturator which consists of two shutters and an interrupted ring of soft iron located so as to be near the focus of the mirror, the axis of the carbons passing through the center. The obturator is suspended rigidly in position by two brass straps fastened to the top of the drum. In some of the more recent types of projector, the obturator is supported from the bottom of the drum.

Shutters are for the purpose of preventing the direct rays of the light from leaving the drum. They are made of brass, asbestos, or graphite, the latter being used entirely for the large lamps. The figure shows an old construction of obturator. In the newer ones the construction is different, in that the shutter is one solid

* The feed mechanism is discussed further in the chapter on Power Supply.

piece of graphite and fits in its place by guides instead of being hinged.

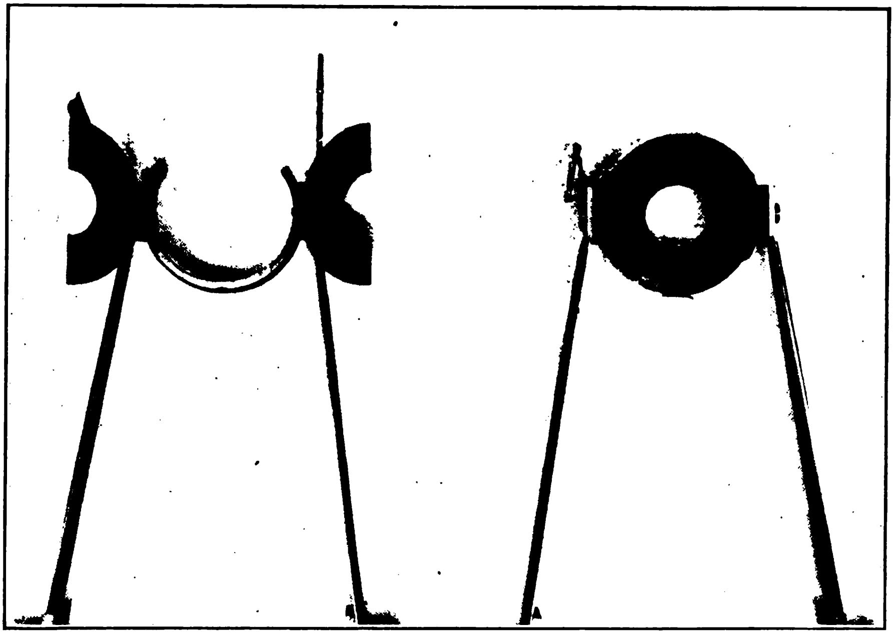


Fig. 7. Obturator.

The circular piece of iron is to prevent the arc stream from wandering; the magnetic flux of the iron, produced by the arc current, acts on the stream tending to keep it properly centered.

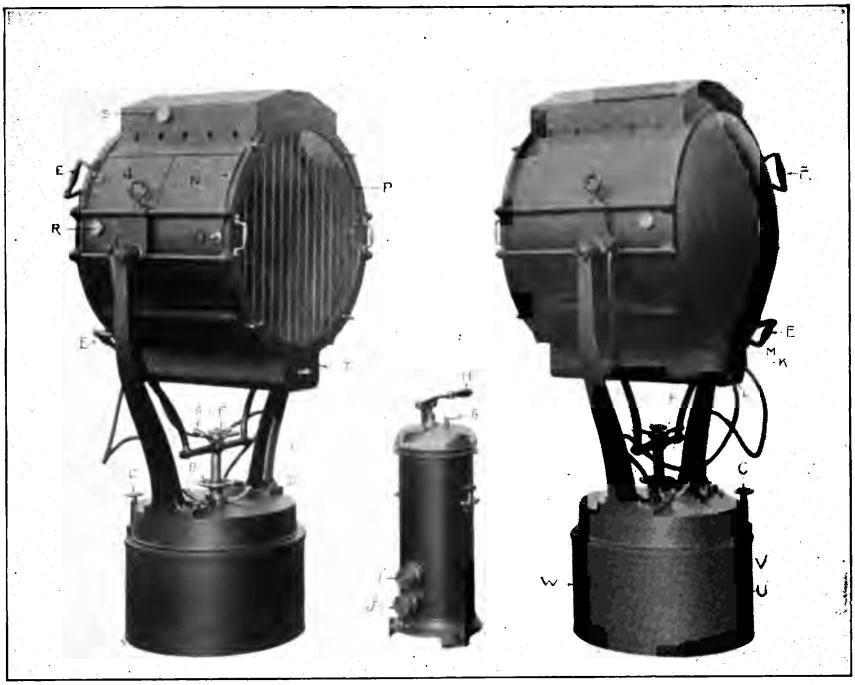


Fig. 8. Old Type Projector and Controller, 7-Wire.

A. Hand star wheel for slow vertical training (hand control).
B. Clamp nut for horizontal training clutch nut.
C. Hand wheel for slow horizontal training (hand control).
D. Nut for horizontal training clutch.
E. Wood handles for quick hand control.
F. Clutch for throwing out vertical training mechanism for hand control.
G. Controller switch.
H. Controller handle.
I. Controller fuse blocks.
J. Plug receptacle for controller cable.
K. Focusing screw for bringing rays of beam sensibly parallel.
L. Socket for inserting wrench for operating feed magnet switch.
M. Socket for inserting wrench for feeding lamp by hand.
N. & Q. Sliding doors used for adjusting lamp and cleaning mirror and front door.
O. Door used when adjusting or changing carbons.
P. Glass front door for protecting arc.
R. Side peep sight for observing condition of arc.
S. Vertical peep sight for observing when crater is in focus.
T. Lamp case.
U. Main lamp switch.
V. Latches for fastening base apron.
W. Base apron for protecting training mechanism.

CHAPTER II.

THE OLD SEARCHLIGHT

As has been said the old searchlight differs from the new in its electric control mechanism, one being for short distance, the other for long distance control. There are many of the old type still in service and these may be divided into two general classes, namely

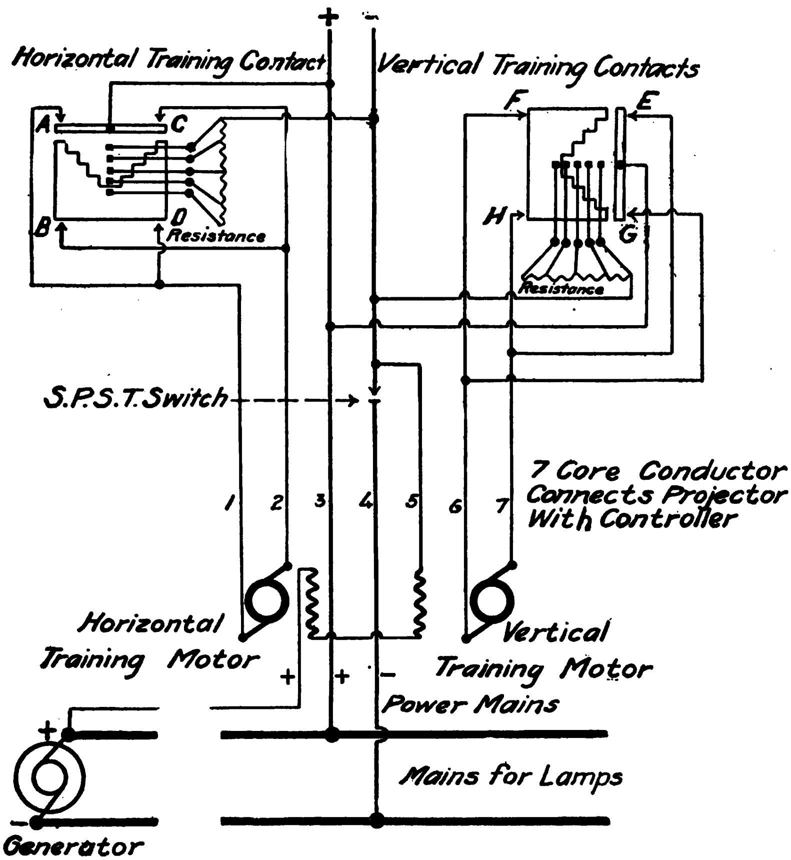


Fig. 9. Sketch of 7-wire controller circuits.

the 7-wire and 6-wire controller types, the latter being an improved pattern of the former. The objection to the old searchlight is its method of electric control, *i.e.* taking the armature currents

through the controller which allows a radius of control of but about 150 feet.

THE 7-WIRE CONTROLLER SEARCHLIGHT

The names of the parts of this projector are given in Fig. 8 and the control mechanism is shown in Figs. 13, 14 and 15.

Figs. 9 and 10 show the circuits of the controller, Fig. 9 being a diagrammatic sketch. The fields of the motors are in series and the exciting current is carried through the controller in order that

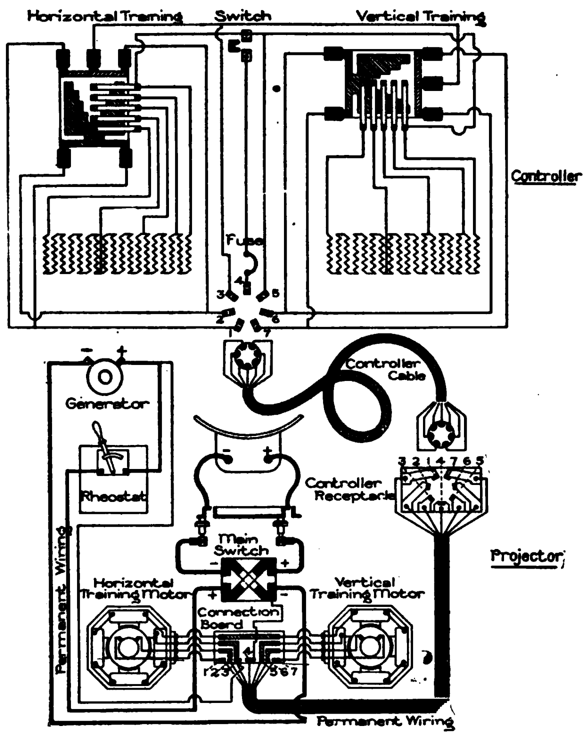


Fig. 10. Connections in detail for 7-wire projector.

it may be made and broken there; the direction of rotation of the motors is reversed by reversing the direction of the current in the armature circuit; the speed of the motors is changed by changing the resistance in the armature circuit, and, there being four resistances for both horizontal and vertical training, there are five speeds for each; seven wires are necessary between the controller and projector; and three wires are required between the projector and power plant; one of these wires is for the motor fields and should

Fig 11.

Fig 12.

7-Wire Controller.

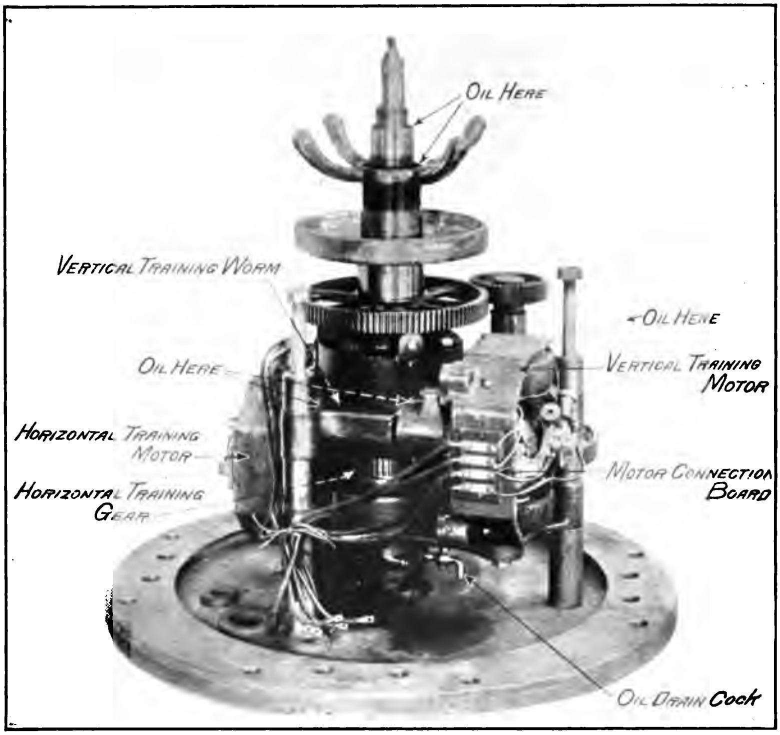


Fig. 13. Training Mechanism, 7-Wire Projector.

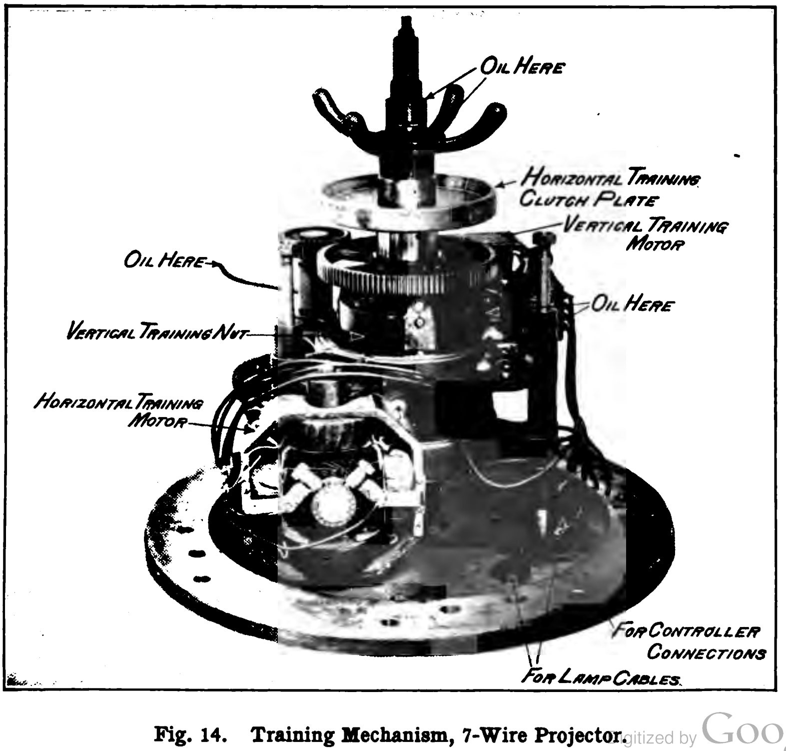


Fig. 14. Training Mechanism, 7-Wire Projector.

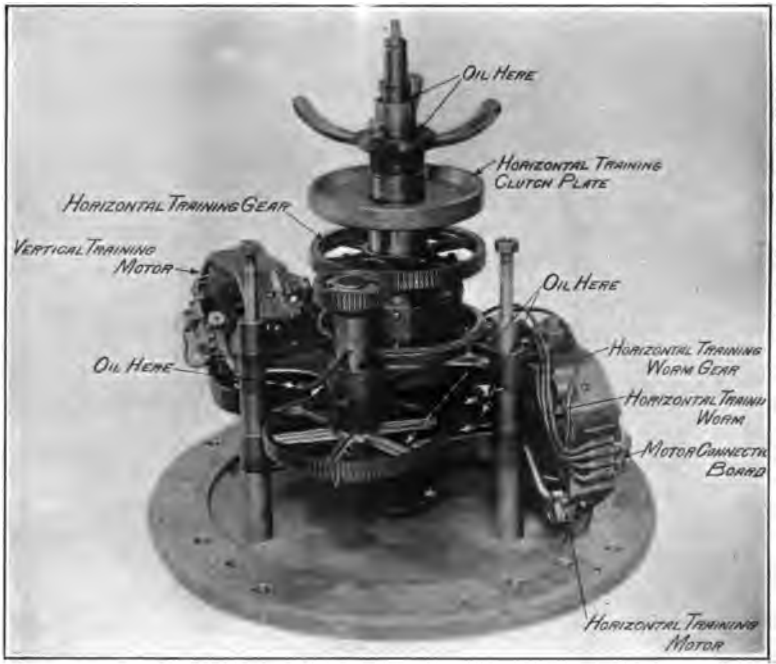


Fig. 15. Training Mechanism, 7-Wire Projector.

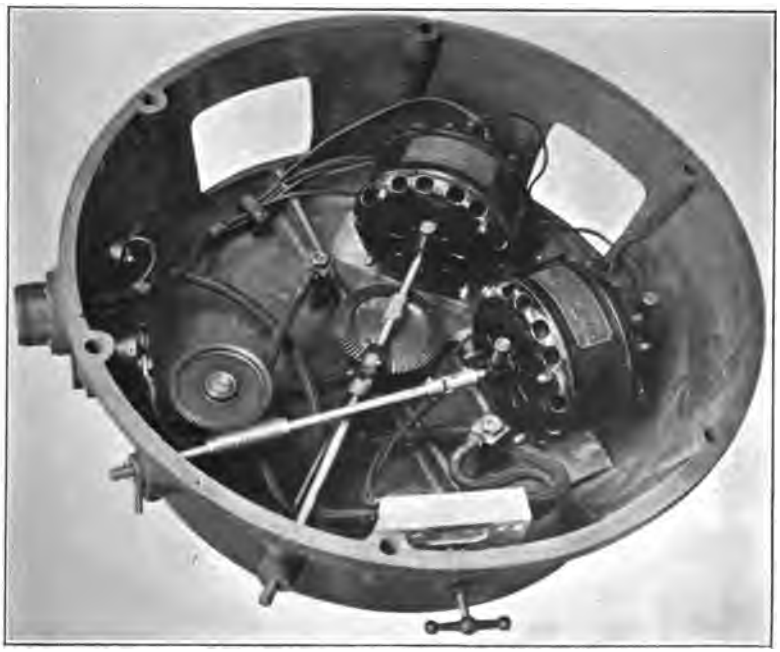


Fig. 16. Training Mechanism, 6-Wire Projector.

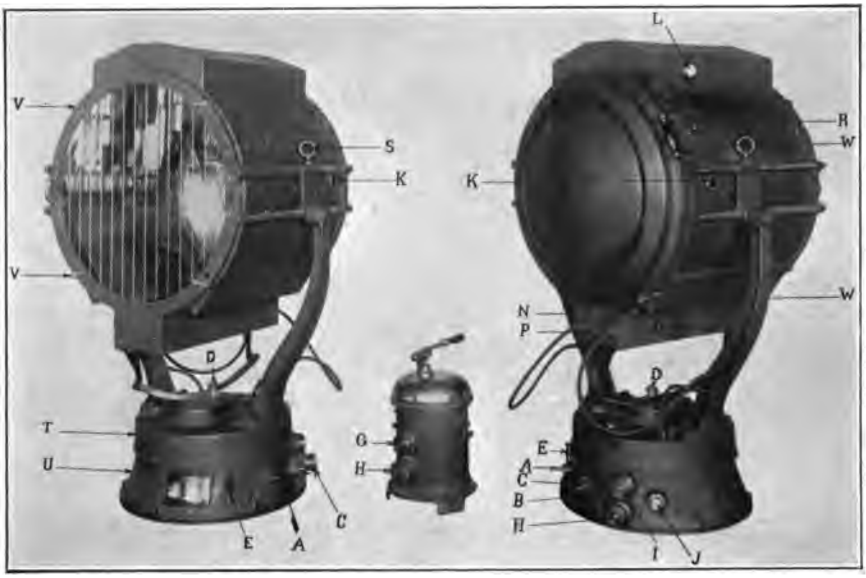


Fig. 17. Old Style Projector and Controller, 6-Wire.

A. Shaft for slow vertical mechanical training.
B. Eccentric for throwing out horizontal training gear.
C. Shaft for slow horizontal mechanical training.
D. Clutch for throwing out vertical training mechanism for quick hand control.
E. Main lamp switch.
F. Controller handle.
G. Controller fuse block.
H. Receptacle for controller cable coupling.
I. Receptacle for main line cable coupling.
J. Receptacle for motor wire.
K. Side peepsight.
L. Vertical peepsight for observing image of crater.
N. Socket for inserting wrench for feeding lamp by hand.
O. Focusing screw.
P. Socket for inserting wrench to operate feeding magnet switch.
R. Doors for adjusting lamp.
S. Clamp for adjusting balance of drum.
T. Turntable.
U. Pedestal.
V. Latches for securing glass front door.
W. Handles for controlling beam by hand.

not have a total resistance exceeding .05 ohms, this arrangement being necessary in order to maintain the proper strength of fields.

Figs. 11 and 12 show photographs of the controller. The big base is necessary on account of the large amount of resistance used.

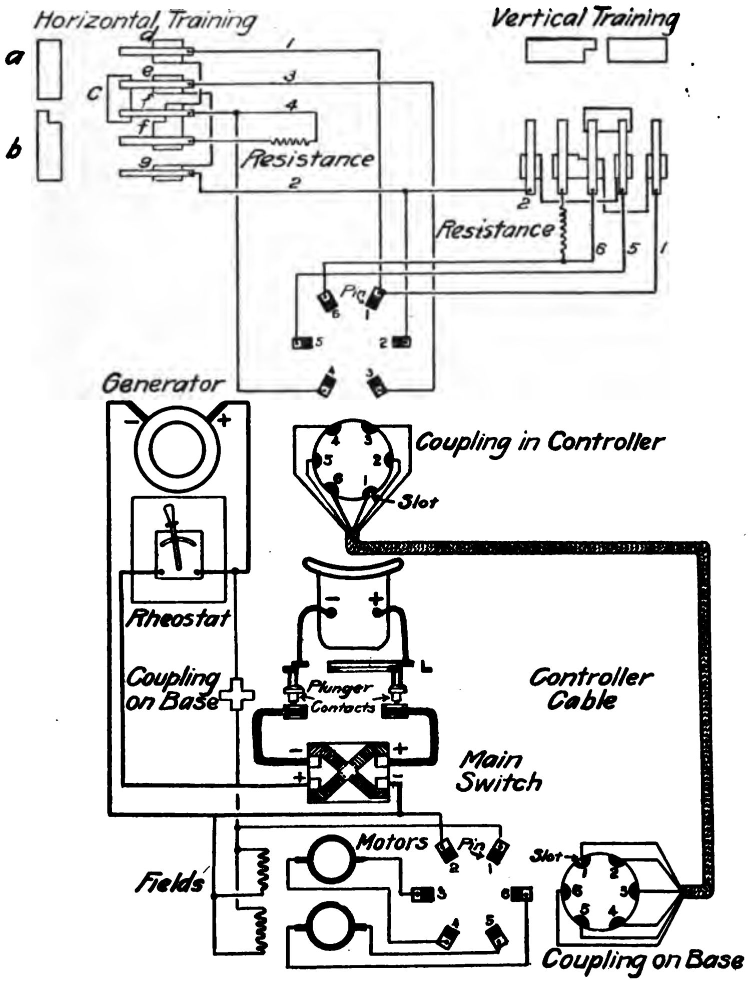


Fig. 18. Connections in detail for 6-wire controller.

To use the controller the switch handle on top must be turned to the position marked "on."

For horizontal training move the controller handle horizontally in the direction it is desired to move the beam. When moved to the right, contacts A and B are opened leaving C and D closed, see Fig. 9, the circuit being positive lead, C, 2, horizontal

training motor, 1, D, resistance, and negative power lead; this starts the horizontal training motor, and its speed depends upon the amount of resistance put in, which is regulated by the position given the controller handle as the contacts completing the circuit depend upon this. When moved to the left the direction of rotation of motor is changed because the direction of current is reversed. In this case C and D are opened leaving A and B closed, the circuit being positive lead, A, 1, horizontal training motor, 2, B, resistance and negative power lead.

As soon as the controller handle is released a spring brings it back to the initial position. In this position contacts A, B, C and D are made, and the motor, is shortcircuited with a full field, the object being to stop the armature quickly. If this were not done the momentum of the armature and other moving parts would cause it to rotate after the current ceased, interfering seriously with the accurate control of the beam.

The shortcircuiting of the motor has the following effect: As soon as the power is cut off the machine ceases to be a motor and becomes a generator, and by short circuiting it as a generator, a heavy current begins to flow, which acts on the magnets' field producing a large torque that stops the machine almost instantly.

The vertical training is done in a similar manner to that of the horizontal training; for one direction E and F are broken and for the other direction G and H are broken.

The sizes of the seven wires between the controller and projector vary with the distance between the two; below is given this data as well as the maximum allowable resistance for each wire:

Number of conductor	Sizes of wire B & S gauge			Maximum resistance in Ohms
	50 feet	100 feet	150 feet	
1	14	11	9	.14
2	14	11	9	.14
3	11	8	6	.07
4	10	7	5	.05
5	14	14	14	.62
6	14	11	9	.14
7	14	11	9	.14

THE 6-WIRE CONTROLLER SEARCHLIGHT

This type is an improvement on the other. Fig. 17 shows the names and parts of the projector. The control mechanism is shown in Fig. 16.

The control is very much the same as the other old pattern. One resistance only is used and the field current is not taken through the controller, see Fig. 18, consequently this method gives two speeds and requires six wires; otherwise it is practically the same as in the 7-wire type.

When the controller handle is moved horizontally through the proper angle, to the right for example, the first speed is obtained, the circuit being: generator positive, l, d, f, resistance, 4, horizontal training motor, 3, e, g, 2 and generator negative. The second speed is obtained by moving the handle through an angle slightly greater in the same direction, in which position, the circuit is completed with the resistance cut out.

In releasing the handle a spring brings it back to the neutral position and here the motor is shortcircuited with full field, bringing the armature to a stop quickly, the circuit being: motor, 3, C, 4 and motor.

When the handle is moved to the left, two speeds may be obtained in the opposite direction since the contacts on this side reverse the direction of current through the motor's armature.

The vertical training is accomplished in a similar manner to the horizontal training.

CHAPTER III.

THE NEW SEARCHLIGHT

The new searchlight is an improvement of the older types: its electric control permits a longer radius of operation, the armature currents are not taken through the controller, and the circuits are made and broken by means of magnetic relays operated from the controller. In the relay circuits very small current is required, not more than one-tenth of an ampere. The radius of control has been tested out satisfactorily in practice for distances as great as several thousand feet. In a shop test the equivalent of 16,000 feet of cable was used successfully.

The new searchlights may be divided into two classes, the 9-wire and 8-wire controller types; the chief difference being in their control mechanism.

THE 9-WIRE CONTROLLER SEARCHLIGHT

A large number of these have been installed in the last two or three years, all being either the 36 or 60 inch sizes, except in a few cases. The parts of the 36-inch will be seen from an examination of the various photographs and drawings.

A 36-inch installation is shown in Fig. 19, everything being in its proper position except the controller. In general, it may be said that the controller is located in the mine, fire, or battle commander's station. Fig. 20 shows the same searchlight dismantled, Fig. 21, the training mechanism, and Fig. 22, the relay switch box with the top removed. In many of the 36-inch, the relay switches are located in the pedestal, see Fig. 24; however, with this exception, all are substantially the same as the one shown in the photograph.

The 60-inch differs in construction only slightly from the 36-inch. Fig. 25 shows a 60-inch installation. In this size the vertical training motor is fastened to the turntable. Figs. 26 and 27 show the magnetic clutches and gearings and Figs. 30 and 31 the relay switches.

Fig. 23* gives a cross-sectional view of the base of a projector showing the training mechanism and underneath the names and functions of the parts are given.

Fig. 24 is a plan of same.

* This drawing is of the 30-inch; however, the larger size differs but slightly.

Fig. 19. 36 Inch Installation, 9-Wire.

Fig. 20. Parts of 36 Inch Projector, 9-Wire.

Fig. 21. Training Mechanism 36 Inch Projector, 9-Wire.

Fig. 22. Relay Switch Box with Cover Removed.

MECHANISM FOR VERTICAL TRAINING

For vertical training the motion is transmitted from the vertical training motor to the drum so that the beam may be given motion in a vertical plane and this is accomplished as

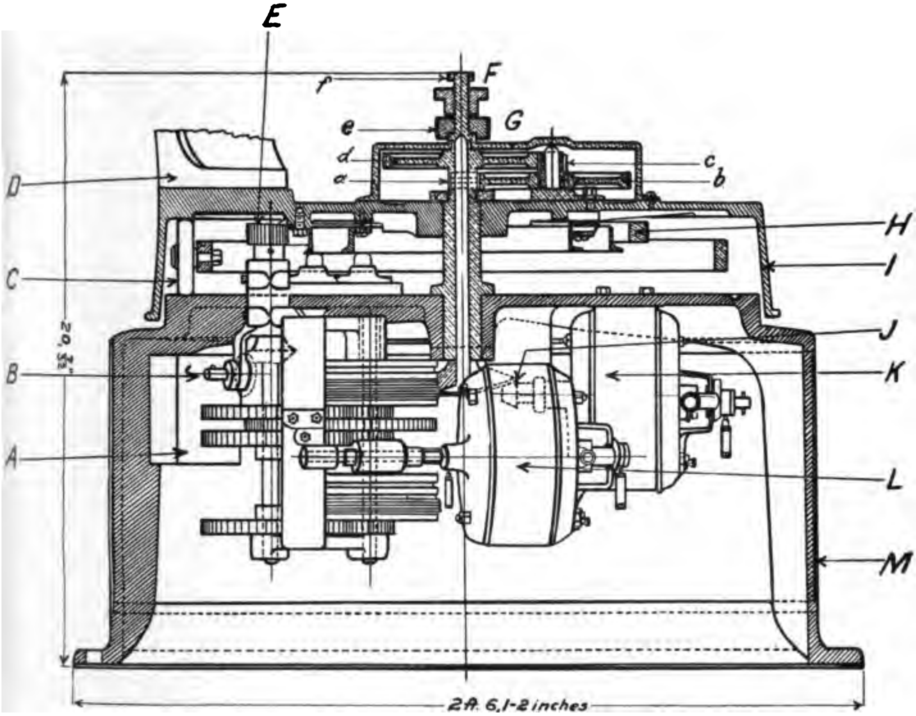


Fig. 23. Vertical section of base of 30-inch projector, 9-wire.

A. Clutches and gear mechanism for horizontal training.
B. Shaft for slow horizontal training (hand control).
C. Turntable roller ring.
D. Standard for holding drum trunnions.
E. Horizontal motion gear wheel, meshes into turn table gear wheel.
F. Clutch for throwing out vertical training mechanism for quick hand control.
G. Reduction gear wheels for vertical training.
H. Turntable gear wheel by which horizontal motion is transmitted to the turntable.
I. Turntable.
J. Bevel gearing for transmitting vertical training motion.
K. Vertical training motor.
L. Horizontal training motor.
M. Pedestal.

follows: The motor K, Fig. 23, transmits motion through a beve gearing J to a vertical shaft passing through the center of the turntable, near the top of which is fastened a spur gear a. Motion

from gear a is carried through a reducing gear train, gears b, c, and d, to a shaft on which gear e is fixed, (so as to be controlled by a hand clutch). Gear e meshes into a vertical rack whose shape is an arc concentric to the axis of the trunnions, see Fig. 19. The drum is pivoted horizontally on trunnions which bear in the standards; hence any motion of e moves the beam in a vertical plane.

The transmission of motion between gear d (*i.e.* reduced motion of motor) and gear e is controlled by a clutch whose handle

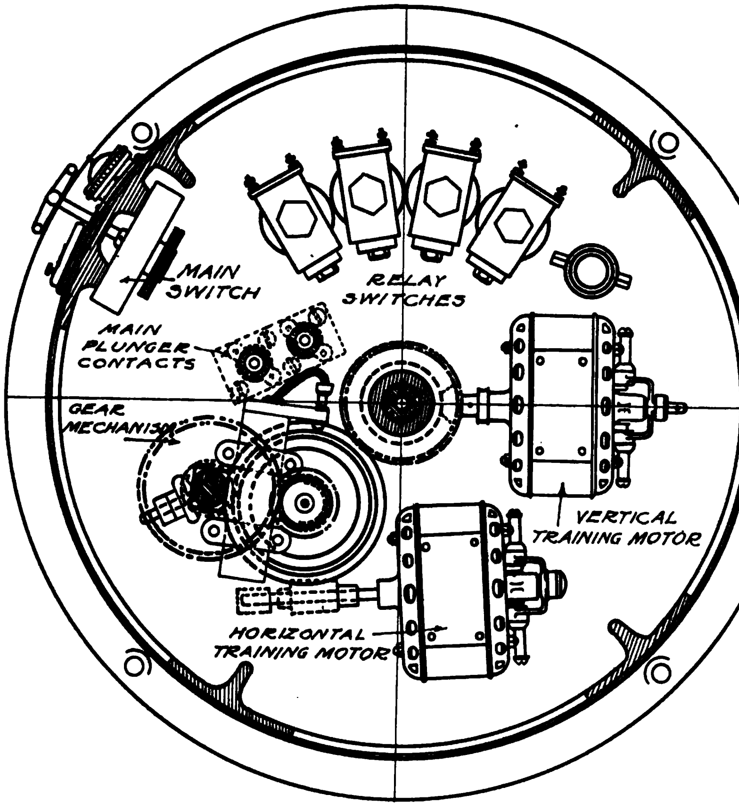


Fig. 24. Plan of base of 30-inch projector, 9-wire.

is F. When F is screwed home the clutch makes gears d and e travel together. When F is unscrewed the clutch is released and motion cannot be transmitted from the motor to the drum or vice versa. It is necessary to loosen the clutch for quick hand control of the vertical motion.

It is thus that the speed of the motor is transmitted to the drum considerably reduced. The motor is run at two speeds;

Fig. 25. 60 Inch Installation, 9-Wire.

the slow speed is obtained by inserting resistance in the armature circuit and the fast speed by cutting this resistance out.

MECHANISM FOR HORIZONTAL TRAINING

For horizontal training, the motor L, Fig. 23, transmits its motion by a worm gear to either of two gear trains, having different speed ratios and controllable by magnetic clutches, which end with gears solid on the shaft containing pinion E. Pinion E meshes in the large gear H on the turntable concentric to its center of motion. Since the turntable rests on a roller ring C, bearing

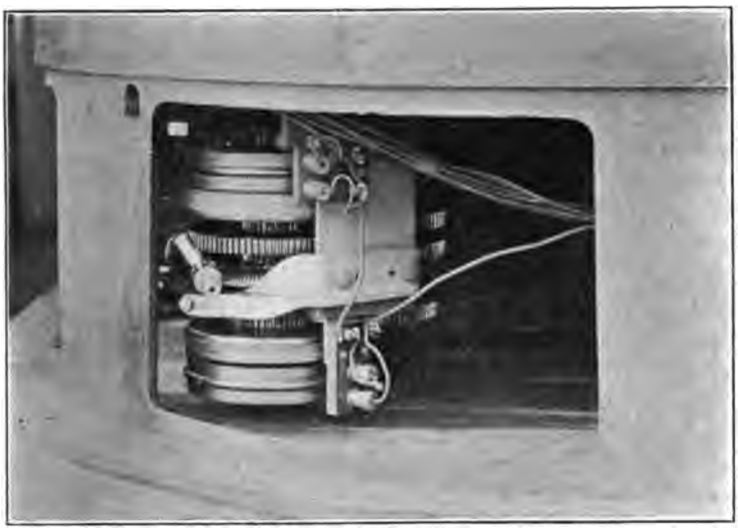


Fig. 26. Mechanism for horizontal training, base of 60-inch projector.

on a horizontal plate, see Fig. 20, horizontal motion may be transmitted with two speeds depending upon which gear train is operated. Two other speeds are obtained electrically by the insertion and cutting out of a resistance in the armature circuit.

The clutches grip through friction produced by the attraction of the electromagnets and their armatures. The energizing is governed by the controller, current being brought and returned to the electromagnets by plunger contacts, which bear on copper rings insulated and connected to the magnet coil terminals, see Fig. 26, and the circuit being made or broken by the controller.

The operation of the motor in putting either gear train in motion through the clutches may be understood by examining

the photograph in Fig. 26,* and the diagrammatic sketch of same in Fig. 27.

When the horizontal training motor is running and neither clutch is energized, both electromagnets J and A, Fig. 27, turn with different speeds, and the turntable and beam remain motionless. This is accomplished as follows: On the motor shaft is a worm D which meshes into and therefore turns gear E. Since E is solid to the electromagnet A, both move with the same speed. E is also solid to gear F which meshes into the reducing gear N, and N is solid to gear M, the latter meshing into reducing gear G, which is solid to the electromagnet J, therefore J moves with a slower speed than A. The turntable shaft P does not move because M and N run idly on it and gears C and H slide on sleeve bearings. (That is, until their respective electromagnets are

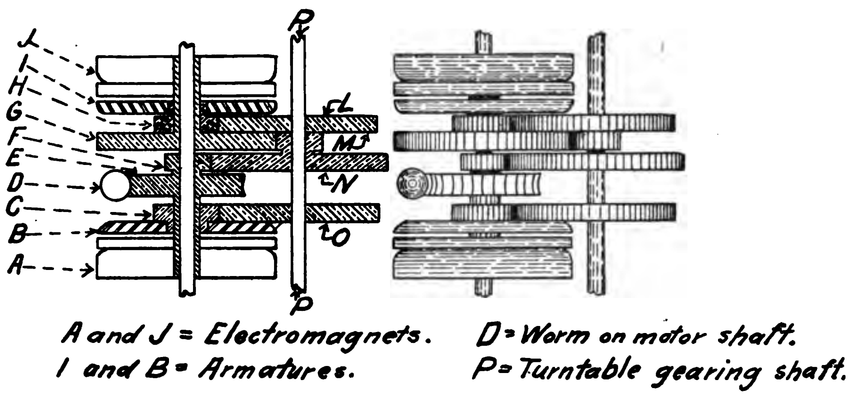


Fig. 27. Sketch of horizontal training mechanism in 9.wire projettor.

energized.) If the electromagnet A is energized, while the motor is running, the fast speed is given the turntable; for A being energized attracts its armature B giving it motion and gear C is solid to B and meshes into gear O which is keyed to P, thus bringing the motion to the turntable. In a similar manner electromagnet J transmits the motion of the motor to the turntable since L is keyed to the shaft P.

When the clutches are inoperative the beam may be controlled by hand since the turntable moves involving only part of the gearing and not affecting the motor.

* It may be observed that some searchlights have a slightly different arrangement of the fast gear train clutch, the armature being under instead of on top of the electromagnet. See Fig. 57.

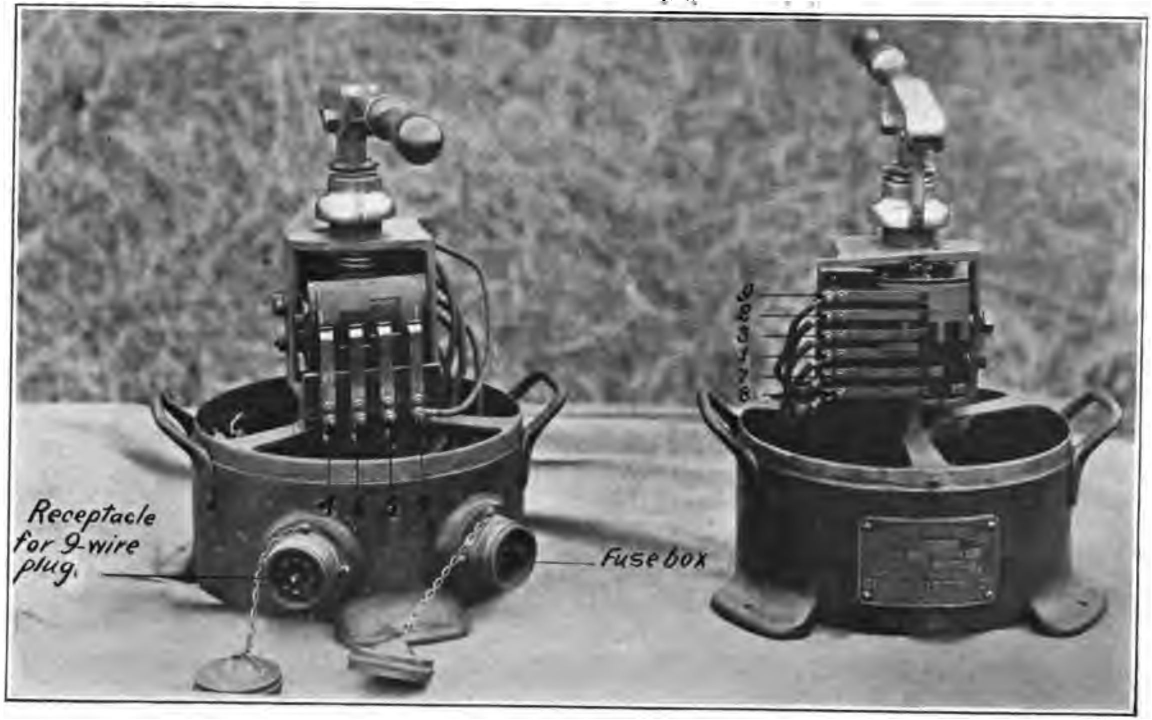


Fig. 28. 9-Wire Controller.

RELAY SWITCHES

The operation of relay switches may be understood by considering the action of one since the rest act in the same manner;

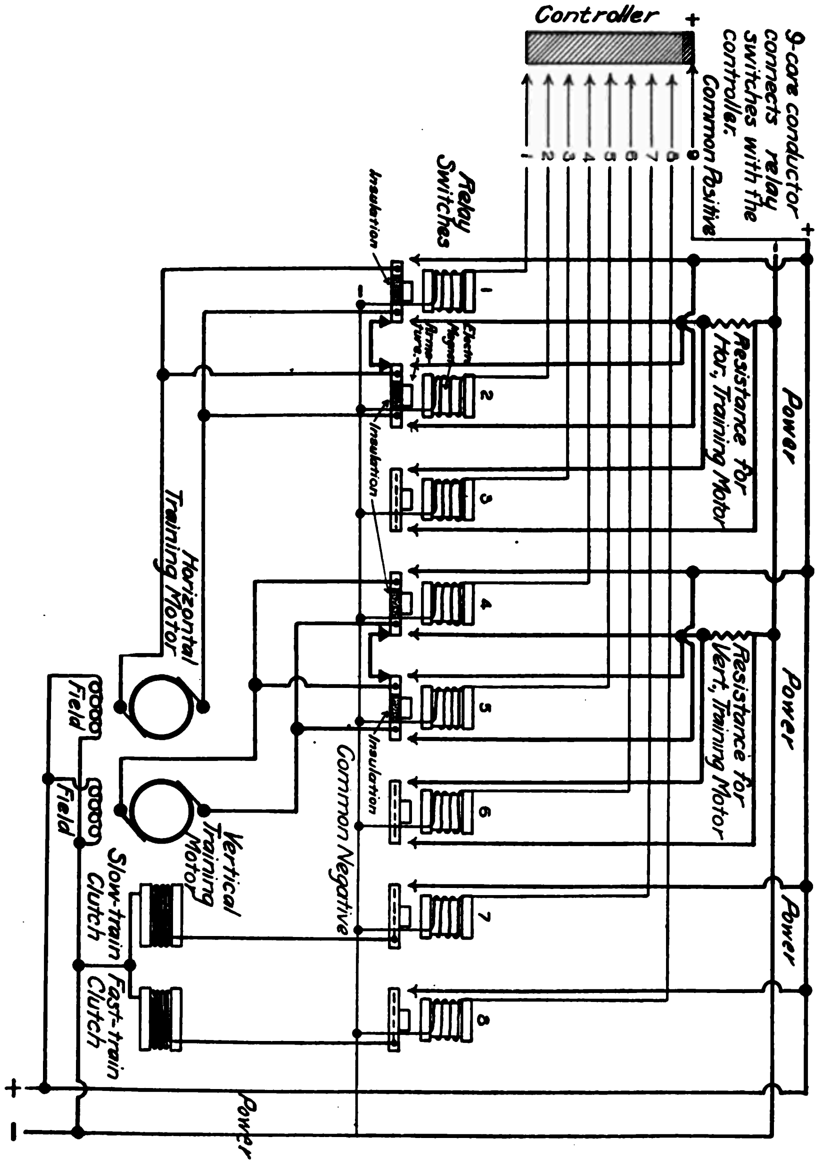


Fig. 29. Sketch of circuits for 9-wire controller.

for example, take the closing of switch 4, Fig. 29. The relay circuit for 4 is positive power main, controller common positive,

finger contact at controller, electromagnet, common negative and finally negative power main. If the power supplied is proper, it is evident that when contact 4 (*i.e.* finger contact belonging to this circuit) is made by the controller, see Fig. 28, the electromagnet of 4 circuit will become energized and attract its armature, which closes switch 4, *i.e.* the motor's switch, and, in consequence, the motor is put in operation with its first speed. The mechanical features of relay switches are shown in Figs. 30, 31 and 32.

VERTICAL TRAINING

For vertical training there are two speeds, one with a resistance in series with the armature and one without, relay switches 4, 5 and 6 being used.

From the diagrammatic sketch, Fig. 29, it may be noted that if relay switch 4 is closed, the vertical training motor will receive current with the resistance in series with its armature; this will put the motor in operation with its first speed; if while 4 is in, 6 is also put in, the resistance would be cut out giving the second speed; if 5 were put in alone, it would give the first speed in the opposite direction, since the current through the motor's armature would be reversed; and finally, if 5 were put in together with 6 the second speed in that direction would be obtained; hence we obtain for vertical training two speeds in either direction.

HORIZONTAL TRAINING

For horizontal training there are four speeds, two obtained mechanically and two electrically. The fastest speed is about fifteen times the slowest speed. As has been said, there are two magnetic clutches each of which transmits motion to separate gear trains with different speed ratios, the clutches being made operative by the controller; the other speeds are obtained electrically by one resistance which may be cut in or out of the armature circuit. The four speeds are obtained as follows: First speed, slow train clutch with resistance in the armature circuit; second speed, slow train clutch without resistance; third speed, fast train clutch with resistance; and fourth speed, fast train clutch without resistance.

Relay switches 1, 2, 3, 7, and 8 are used and their functions may be seen from Fig. 29. Relay switch 1 closes the motor circuit through the resistance, 3 cuts the resistance out, 7 and 8 are for putting in the magnetic clutches, and 2 is for reversing the direction of rotation of the motor.

Fig. 30. Relay Switches for Vertical Training.

Fig. 31. Relay Switches for Horizontal Training.

Fig. 32.
1st. Speed Vertical Training.

Fig. 33.
2d. Speed Vertical Training.

Fig. 34.
1st. Speed Horizontal Training.

Fig. 35.
2d. Speed Horizontal Training.

Fig. 36.
3d. Speed Horizontal Training.

Fig. 37.
4th. Speed Horizontal Training

CONTROLLER

The controller makes certain combinations of contacts governed by the position of the controller handle. Fig 28 shows two views of the controller in its neutral position, the handle being returned to this position by springs whenever released. Either vertical or horizontal motion of the handle draws a cylinder across copper fingers. On each cylinder are copper bearing surfaces, for the fingers, electrically connected to each other and to the common positive but otherwise insulated, and arranged so that the several positions of the controller handle bring about the required combinations.

When the controller handle is moved vertically, two speeds in either direction may be obtained. Figs. 32 and 33 show the two positions of the controller giving the two speeds for vertical training in one direction. The two speeds in the opposite direction are obtained by moving the controller handle oppositely. The finger on the right brings current to the copper surfaces from the common positive wire. The several positions of the controller handle give the following combinations, see Fig. 29, viz:

First speed, 9 is put in contact with 4.
Second speed, 9 is put in contact with 4 and 6.
For opposite direction change 4 into 5 in the above.

When the controller handle is moved horizontally four speeds in either direction may be obtained. Figs. 34, 35, 36 and 37 show the four positions of the controller for the four speeds in one direction for horizontal training. The four speeds in the other direction are obtained by moving the controller handle oppositely. The top finger brings current from the common positive to the copper surfaces and the several positions of the controller handle give the following combinations, see Fig. 29, viz:

First speed, 9 is put in contact with 1 and 7.
Second speed, 9 is put in contact with 1, 7 and 3.
Third speed, 9 is put in contact with 1 and 8.
Fourth speed, 9 is put in contact with 1, 8 and 3.
For the opposite direction change 1 to 2 in the above.

When the controller handle is in its neutral or initial position, it may be noted by an examination of Fig. 29 that both the vertical and horizontal training motors are short circuited, which makes them come to a dead stop for the reasons explained in Chapter II. The controller handle is returned to the initial position by a spring when released; in tracking vessels the handle must be released when it is desired to stop the motion of the beam.

For the connections of the 36-inch controller circuits see Fig. 43, and for same of the 60-inch see Fig. 44.

THE 8-WIRE CONTROLLER SEARCHLIGHT

This searchlight differs from the other new types in its training mechanism, eight wires being used in the controller instead of nine.

The following other changes have been made. The controller handle has no spring return but remains in whatever position placed. Stops are used on the vertical rack to keep it from running off the pinion, the latter being controlled on its shaft by a spring clutch. When the pinion engages in the stop, the clutch ceases to hold allowing the motor to continue moving whereby no damage is done. On the base is a graduated circle and a pointer is attached to the turntable, such that the beam may be placed (by hand control) in any desired direction. The base is constructed better proof against moisture, and the gearing for horizontal training is enclosed in a case where it is submerged in oil.

The general appearance of this light may be seen from the photograph, Fig. 40. In the appendix detail drawings of the training mechanism will be found. (Figs. 58 to 61.)

VERTICAL TRAINING MECHANISM

Vertical motion may be given the beam with the controller through the vertical training motor attached to the turntable, see Fig. 58, current being brought to it through plunger contacts.

The mechanism for bringing the motion of the motor to the drum is as follows: The motor shaft has a worm which meshes into a worm gear, see Fig. 59, on whose shaft is (when the clutch is fast) a bevel gear meshing with a gear on a shaft containing the vertical rack pinion. In the drawing the pinion is shown keyed to the shaft, but, since the drawing was made, it has been decided to fasten the pinion to the shaft by a spring clutch as already explained.

It may be observed, see Fig. 59, that the bevel gears can be disengaged by pulling and turning the clutch handle; this frees the motor and makes the vertical training operative by hand. A prolongation of the pinion's shaft contains a hand wheel which may be used for slow motion.

As in the 9-wire type two speeds are used, accomplished by armature control with one resistance.

HORIZONTAL TRAINING MECHANISM

Horizontal motion can be given the beam by the controller through the horizontal training motor located in the base, see Fig. 58. As in the other new types, two speeds are obtained by two gear trains having different speed ratios and two by armature control.

The horizontal training gear mechanism is shown diagrammatically in Fig. 39. A drawing of this is given in Figs. 60 and 61. There are two gear trains which carry the motion of the motor to the turntable, one is direct and the other an epicylic gear train. The former gives a speed fifteen times the latter. Whichever gear train is in use, is controllable by an electromagnet operated by the controller.

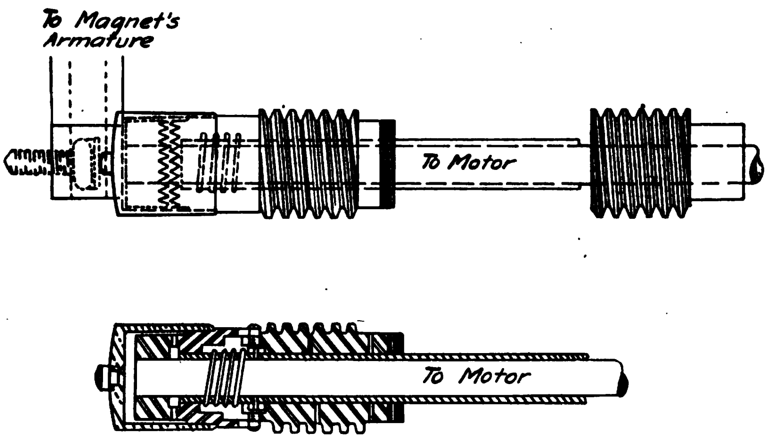


Fig. 38. Clutch in 8-wire projector. (Controls speed ratio of gear trains.)

Direct gear train. For this gear train to act worm E, Fig. 39, is released from the motor shaft L (effected by the electromagnet's armature releasing the clutch, see Fig. 38) and shaft L actuates worm H only. H meshes in worm gear G which is solid with gear O. O turns idly on shaft J and meshes with gears C and N, and turning them, causes gears A and P to turn, for C and A and N and P, respectively, have shafts which have bearings in gear R. (In this case R is stationary). Gears A and P both mesh with gear Q which is keyed to the shaft J and their motion causes shaft J to turn. J has a gear I which meshes into gear K, and the turning of J causes K to turn. K is solid to the turntable. Hence we have the motion of the motor brought by a direct gear train to give horizontal training.

Epicyclic gear train. For this gear train to act, the electromagnet causes the clutch to hold worm E solid to the shaft. Worm E meshes into worm gear D, on whose shaft is keyed gear B, and B meshes into gear R, R being loose on shaft J. This brings into effect an additional gear train, so to speak, to that of the direct gear train and this applies two motions simultaneously. Since the effect of the other gear train is opposite, that is differential, we get a reduced speed for the turntable. Acting alone the direct gear train, starting with worm G, gives the turntable say one revolution per minute. The other gear train starting with worm E, if acting alone, (to do this H would have to be released and gear A and P locked to Q) would give the turntable $\frac{14}{15}$ of a revolution per minute in the opposite direction. If they act simultaneously the turntable gets a motion of $\frac{1}{15}$ of a revolution

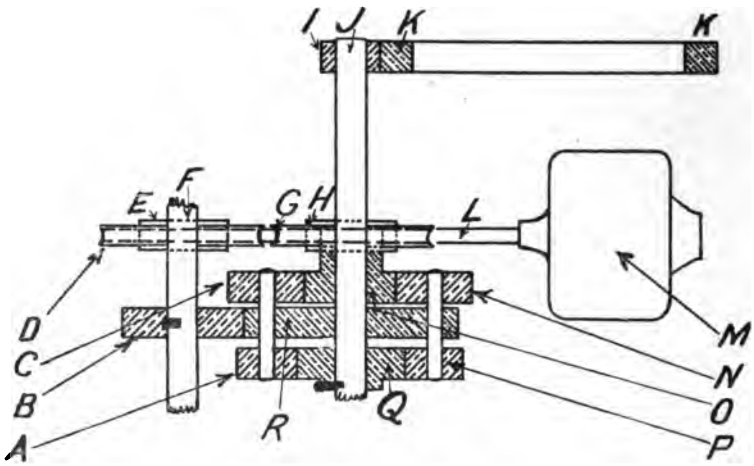


Fig. 39. Sketch of horizontal training mechanism for 8-wire controller.

per minute. The combination is an epilyclic train because the gear Q receives its motion from gears A and N which have two rotations, one about their own axis and another about that of Q.

The action of the clutch control may be seen from Figs. 38 and 60. A spring normally holds the clutch in action, that is, closes the clutch so that the worm revolves with the shaft. As we have seen, in this case the turntable gets its motion through the epicylic train, giving a slow training speed. But, when the clutch electromagnet is energized, the motion of its armature is transmitted mechanically so as to open the clutch, and this releases the worm from the motor shaft, *i.e.* the two cease to revolve together, which allows motion to the turntable through the direct gear train only and this gives the fast training speed.

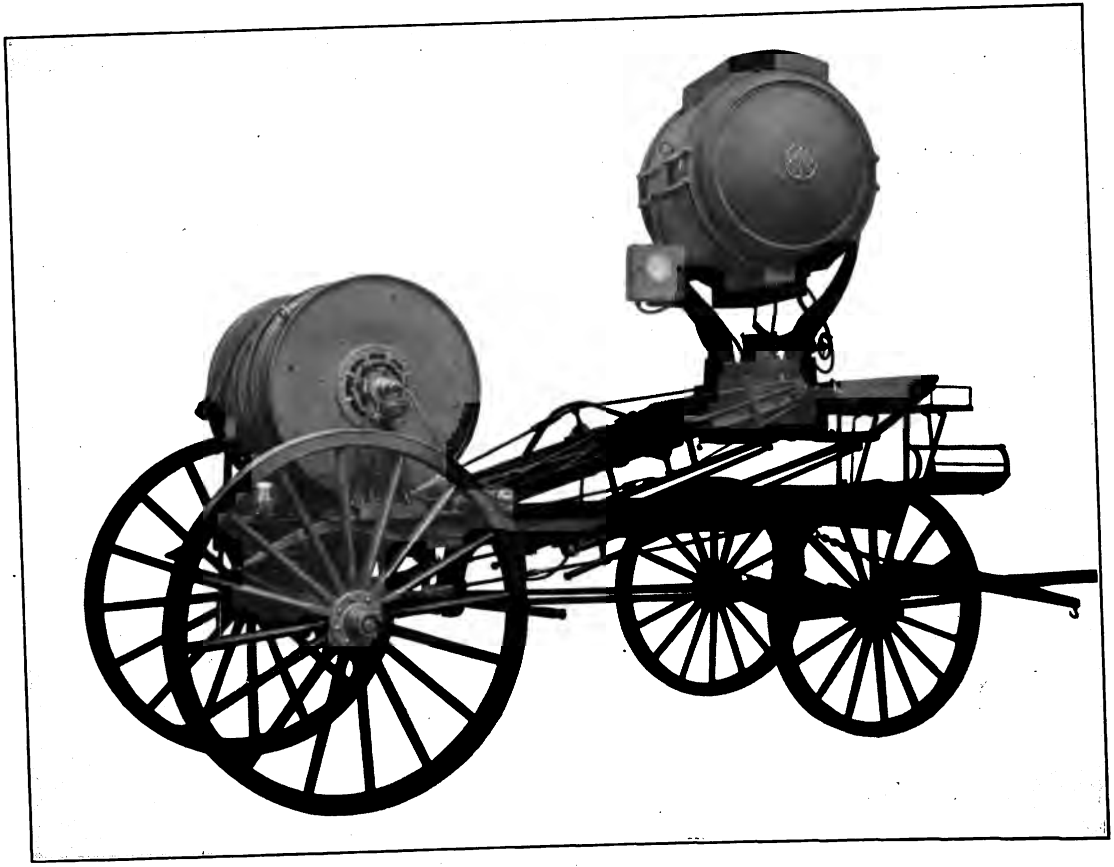


Fig. 40. Portable 36-Inch Projector.

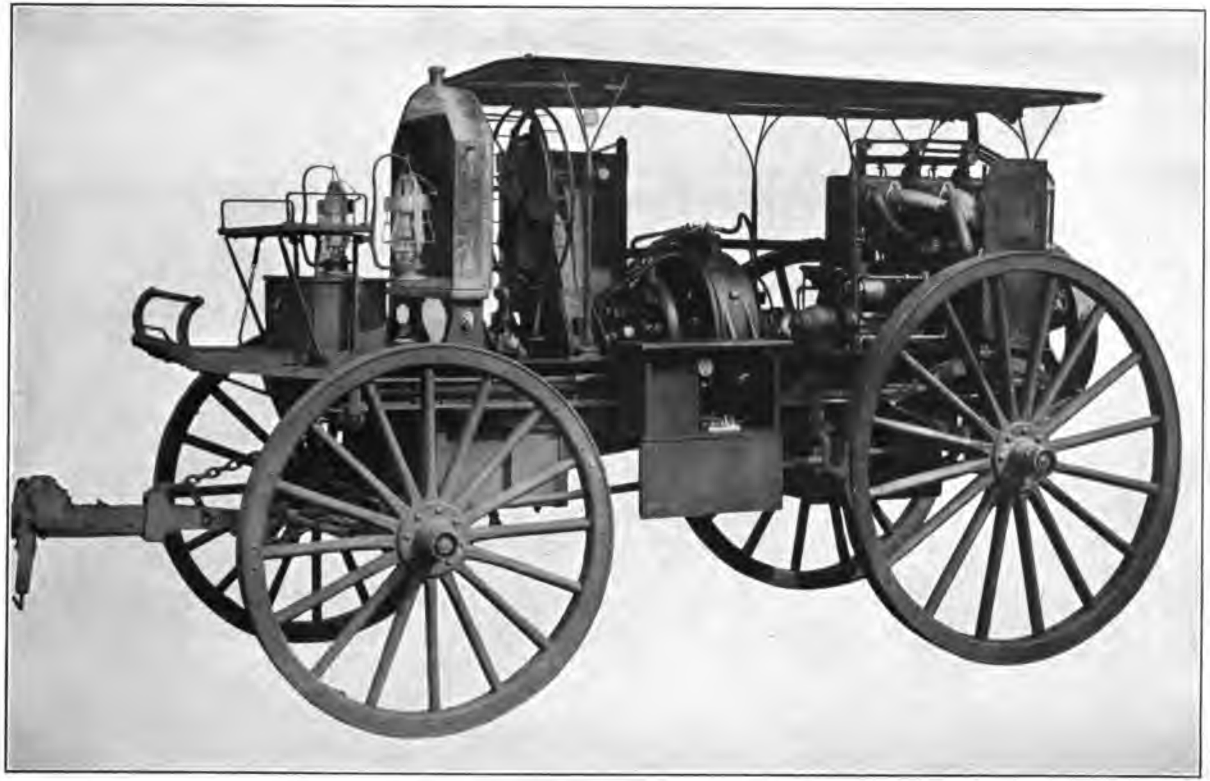
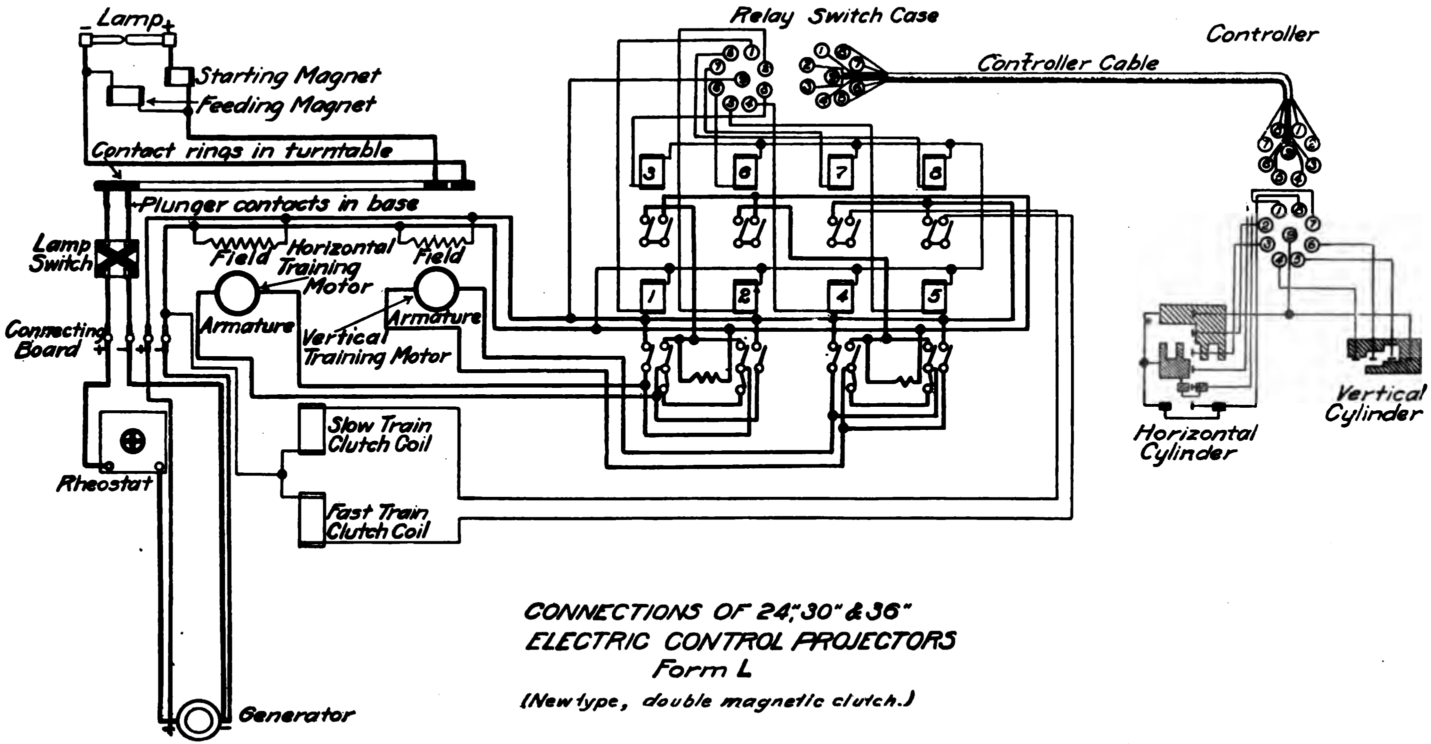


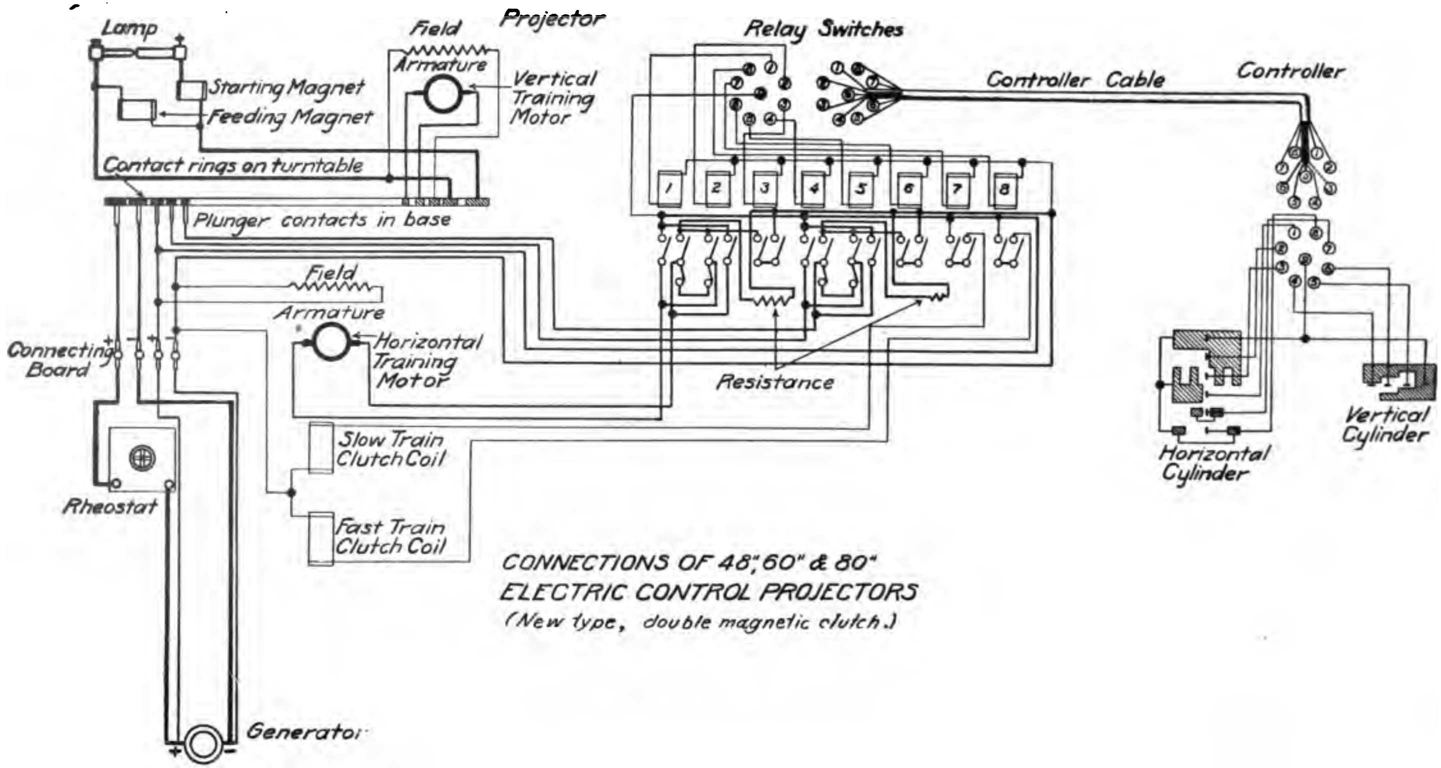
Fig. 41. Portable Power Plant for 36-Inch Projector.

Fig. 42. Portable Power Plant for 36-Inch Projector.



CONNECTIONS OF 24", 30" & 36"
ELECTRIC CONTROL PROJECTORS
Form L
(New type, double magnetic clutch.)

Fig. 43.



CONNECTIONS OF 48", 60" & 80"
ELECTRIC CONTROL PROJECTORS
(New type, double magnetic clutch.)

Fig. 44.

CONTROLLER

The controller is more compact in form than the other new type but its general construction is similar, and, as has been mentioned, no spring return is used for the handle. A change has been made also in that the speeds are marked and a pointer indicates which speed is being used.

By examining Fig. 45, it may be seen that the circuits are practically the same as the 9-wire type, the chief difference being one electromagnet is required making but eight wires necessary.

For vertical training, relay switches 4, 5 and 6 are used; switch 4 puts the vertical training motor in circuit with the power with a resistance in series with its armatures; switch 6 shunts the resistance out of the armature circuit; and switch 5 reverses the direction of current through the armature. The controller causes the following, viz:

First speed, 8 is put in contact with 4.
Second speed, 8 is put in contact with 4 and 6.
For opposite direction change 4 to 5 in the above.

For horizontal training, relay switches 1, 2, 3 and 7 are used; switch 1 puts the horizontal training motor in circuit with the power with a resistance in series with its armature; switch 3 shunts the resistance out of the armature circuit; switch 2 reverses the direction of current in the armature circuit; and 7 causes the electromagnet to open the clutch. The controller causes the following, viz:

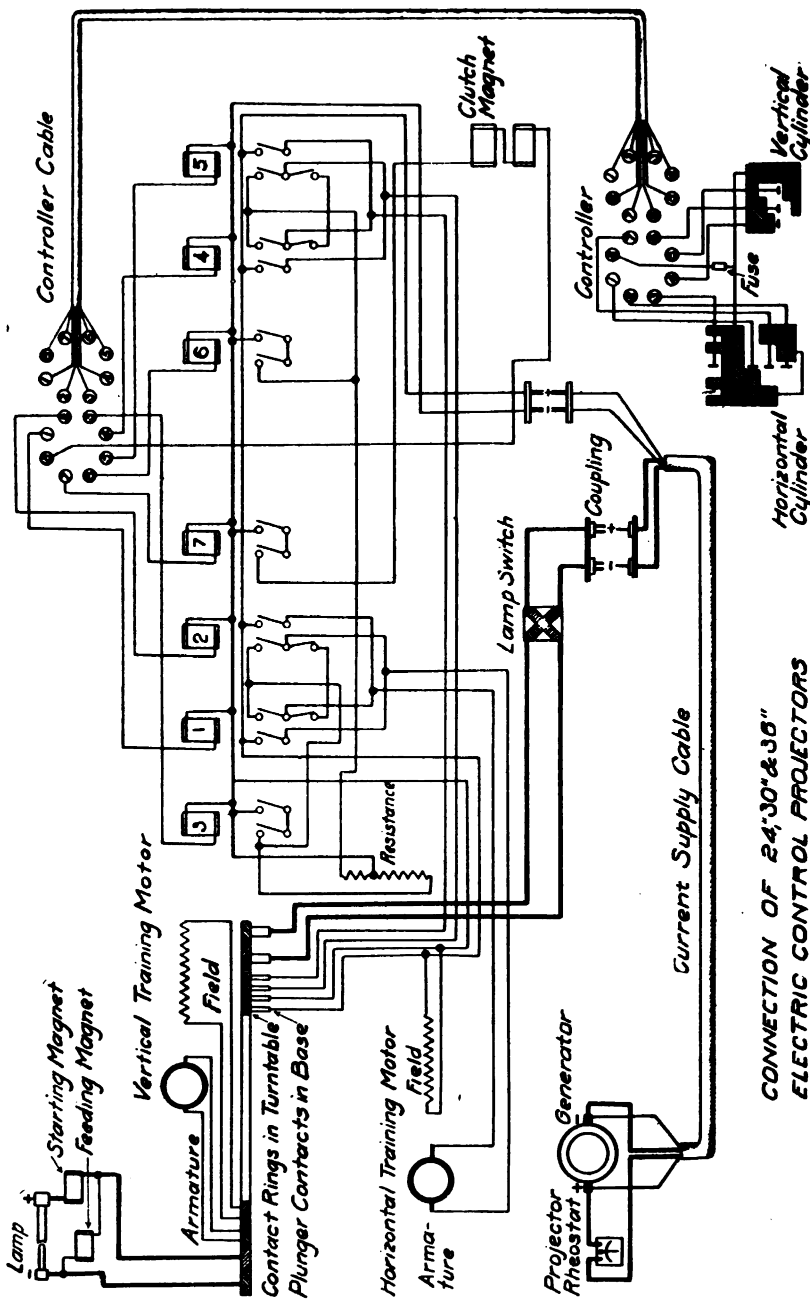
First speed, 8 is put in contact with 1.
Second speed, 8 is put in contact with 1 and 3.
Third speed, 8 is put in contact with 1 and 7.
Fourth speed, 8 is put in contact with 1, 7 and 3.
For opposite directions change 1 to 2 in the above.

In either vertical or horizontal training a spring brings the handle back to neutral or initial position whenever released; this shortcircuits the motor on a full field which stops rotation instantly.

HAND CONTROL MECHANISM

In this type the hand control mechanism is greatly improved and will no doubt give satisfaction. Though hand control is not for general use, it is of importance nevertheless since it is an auxiliary in case of accident to any of the parts on which electrical training is dependent.

Hand control for vertical training is made operative by the releasing of a clutch whose handle is marked showing which



CONNECTION OF 24", 30" & 36" ELECTRIC CONTROL PROJECTORS
Form M
(New type, single magnetic clutch.)

Fig. 45.

position it should be put in to allow hand control. This mechanism is shown in Fig. 59.

Hand control for horizontal training is controlled also by a clutch, see Fig. 60. The clutch handle may be placed in three positions, the following being accomplished: (1) Shaft J can be made solid to pinion I through a jaw clutch, thus making the turntable operative by electric control. (2) Pinion I can be released from shaft J so that it turns idly, putting the turntable free for quick hand control. (3) Pinion I can be made solid through a jaw clutch to a worn wheel which engages with a worm on whose shaft is a hand wheel, this arrangement being for slow hand control. This mechanism is shown in the figure referred to above. It may be noted that the gear I is put in its different positions by the clutch handle on the hand wheel. Each position for the handle is marked.

PORTABLE SEARCHLIGHT SET

The necessity for some form of portable searchlight has been long felt and one or two types have been designed. Figs. 40, 41 and 42 show a portable set of recent make of which quite a number have been purchased. These were constructed for coast artillery purposes and are suitable to be taken on fair roads at ordinary speeds.

As may be seen from the photographs the power plant and searchlight are mounted on separate trucks, each to be drawn by a pair of horses. The power plant and its truck complete weigh 6,580 pounds, and the searchlight and its truck complete weigh 5,800 pounds. The large figure for the latter is due considerably to the weight of the cable, the power cable being 500 feet of four conductor cable (one pair being 90,000 c.m.) and the controller cable 1000 feet of eight conductor cable. Both trucks are equipped with brakes.

SEARCHLIGHT TRUCK

This truck carries the searchlight, a cable reel, and a mechanism by which the light may be elevated, keeping it in its vertical position.

The mechanism referred to is as follows: A pair of arms are fastened to the truck through pivots and in a similar manner connected to the projector's base, see Fig. 40. These arms are heavily constructed and carry most of the weight. A pair of arms of light construction are similarly connected below and to one side on the truck and to an extension from the projector's base,

making a four bar* linkage of the form of a parallellogram. The bar between the pivots on the truck being fixed, it is evident that whatever position the mechanism takes, the bar between the pivots on the projector's base and base extensions remains parallel to it. Hence the searchlight will keep upright. Motion for moving the light up and down is obtained through a bell crank fastened to a cross-arm at about the middle of the two upper bars, the other arm containing a nut into which a screw engages. By turning the screw the light may be raised or lowered as desired. The screw is turned by a crank, the handle being removable. When the projector is put in its elevated position, it may be further supported by means of an auxiliary bar, shown loose in the photograph. This support may be necessary in high winds to give stability.

The projector itself is the 8-wire type already described. It is equipped with a voltmeter and ammeter, mounted in the same case, attached to one of the drum supports. A platform for the attendant extends from the base. This platform folds up when the projector is brought down on the truck. The cables are carried on independent reels mounted side by side on the same shaft.

Plug and socket joints are used for the cable connections. In connecting up the projector the two cables are drawn from the reel and the plugs inserted in the sockets of the generator and exciter respectively. The other ends of the cables are brought through the reel shaft to sockets at its ends, in which the plugs of the lamp cable and training mechanism cable respectively may be inserted.

POWER PLANT TRUCK

This truck carries a 3-cylinder gas engine direct connected to the generator and exciter.

The engine is cooled by water circulation with a gear pump. A small water tank is used and the water after coming from the cooling chambers of the engine is taken to a radiator where a fan is brought to play on it. The fan is of the radial type and belt connected to the engine shaft. A jump spark ignition is used for the engine, the current being furnished the primary from a battery of a few cells. The battery is connected to a small generator (Apple type) through an automatic switch so that it is

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As applied to a mechanism, a bar means a rigid connection between two points.

automatically disconnected when the battery is charged and begins charging whenever the battery becomes slightly discharged. The battery spark coils and switch are all together in a box.

The generator is 9.6 k.w. and runs at 600 r.p.m. It gives 130 amperes at 74 volts. This generator has a series field and a field differential to it, the latter being separately excited. The exciting current is furnished from a $\frac{3}{4}$ k.w. generator mounted on the engine shaft, its voltage being 110 volts. In addition to furnishing the exciting current, this generator furnishes power for the electric control and for four 16 c.p. lamps on the engine truck.

Since the main generator is enclosed and also located close to the engine, it is necessary to use a fan to supply a good circulation of air to keep the temperature down. The fan is of the radial type and belt connected to the engine shaft.

CHAPTER IV.

MANAGEMENT AND CARE OF SEARCHLIGHTS

ACCESSORIES

To promote proper operation, a voltmeter should be connected across the arc, *i.e.* across the lamp terminals, and an ammeter in its circuit, *i.e.* in series with the lamp. Both instruments should have permanent connections and be located where the attendant can see them while adjusting the feed-mechanism whatever the position of the drum.

But it is not usual to supply these instruments. It is claimed they are unnecessary refinements. In their favor the writer claims this—they furnish the attendant information without which he cannot form a fair judgment as to what his light is doing. Though the appearances of the beam and arc, the latter through the peep-sight, are for careful consideration, the most reliable information for what a light is doing is the arc current and voltage. A voltmeter is particularly necessary because it enables the attendant to adjust his automatic feed mechanism when necessary and to feed by hand control should it get out of order. Again these instruments afford a ready means of detecting faulty power supply. The latter sometimes occurs due to negligence on the part of the power-house attendants.

It is well to supply a switch by which the voltmeter may be placed across the terminals of the training motors, for it is important that this voltage be near the rated value, *i.e.* 115 volts for the 60-inch and 100 for the 36-inch.

A double pole switch should be placed in the lamp circuit at the light. This is particularly necessary with the 60-inch because it is not provided with a main switch as in the case of the smaller size.

For convenience, a curved arrow should be marked showing the direction which certain screws should be turned, as follows:

(1) Hand feed screw, N, Fig. 17, to "feed" carbons together.

(2) Focusing screw, O, Fig. 17, to "spread" beam.

NOTE.—This chapter refers to searchlights as operated at present, *i.e.* on constant potential circuits with a dead resistance in the lamp circuit.

(3) Vertical adjusting screw for positive carbon, D, Fig. 2, to "lower" crater.

(4) Horizontal adjusting screw for positive carbon, E, Fig. 2, to move crater "towards handle" of socket wrench when in use.

Every searchlight should be equipped with a tool box containing the following, at least, viz:

2 crank handle socket wrenches, for feeding and focusing screw nuts.

2 plain handle socket wrenches for adjusting alignment of carbons.

3 screw drivers, 6, 10 and 14-inch.

2 pair pliers, 6 and 8-inch.

2 monkey wrenches, 8 and 14-inch.

1 electrician's torch.

1 soldering iron.

2 dust brushes for mirror.

2 dust brushes for lamp.

2 chamois skins.

2 smoked glasses with frame.

3 oil cans, *i.e.* squirt cans, one medium size and two small with long nozzles.

1 air tight can, with convenient cover, that holds a dozen or so positive carbons.

1 air tight can that holds a dozen or so negative carbons.

2 portable electric lights with long flexible cords.

2 lanterns, candle or oil.

2 springs for starting magnet.

2 springs for feeding magnet.

2 pawl springs.

2 contact springs.

2 platinum contacts.

2 contact screws.

In addition to the above the following should be in this tool box, viz: screws, bushings, insulation sheets, solder, soldering composition, tape and several sizes of insulated wire. Perhaps other tools and material might be added but the above will serve as a suggestion. Without question the searchlight attendant should be equipped so that he can repair small breakdowns.

For serious breakdowns, a skilled person in repairs is necessary. For this work, at every district headquarters there should be a Master Electrician or Electrician Sergeant skilled in the repair of searchlights and he should be equipped with the proper tools and material and with all the necessary spare parts of a searchlight;

for example, there should be extra glass front doors, all the important spare parts of the lamp and training mechanism and even extra lamps, gearings and motors. In suggesting the latter, the idea is that, when any of the parts mentioned have to be taken out for repair, good ones can replace them immediately; consequently the searchlight in question would be out of commission necessarily not more than a few hours, whereas otherwise it might be out of commission several days.

The necessity for having spare parts on hand was brought to the writer's attention during the Army and Navy Exercises in 1905. Three lights in which exposure had damaged the insulation of the motor's fields developed open circuits which made the training mechanism useless. Immediately new fields were telegraphed for but, to the writer's knowledge, did not arrive during the exercises though they were ordered a week prior. Fortunately some wire was ordered which arrived in time and one of the electrician sergeants wound the necessary number; these were put in and the training mechanism thereafter functioned properly. In another instance a clutch electromagnet developed an open circuit. This was not repaired by rewinding because two training speeds were left and it was necessary to have the lamp in commission each night. However, if a good electromagnet had been at hand the matter could have been properly repaired within a few hours.

THE LAMP

A lamp functions properly when it maintains the arc in its normal condition and this occurs when the crater emits its light so that normal amount strikes the mirror. This is governed by the area of crater and length of arc stream. The area of the crater depends upon the current and quality and cross-sectional area of carbons, the latter being fixed to suit the current for a given size of lamp; and, assuming these proper, the light which strikes the mirror depends on the current and length of arc.

The proper length of arc for a given lamp occurs when the voltage drop across it is normal, if the normal current is flowing; for example, the 60-inch lamp maintains a normal arc length when the voltage drop is 65 volts and the current is 200 amperes. For other lamps see table on page 2. The voltage drops for the currents given are selected with great care so it is of importance that they should be maintained in practice.

STARTING THE ARC

First

(a) When beginning with a new set of carbons, secure them in their holders with the negative carbon, *i.e.* smaller one, nearest the mirror, observing that they fall nearly in alignment, that is, that the axis of the positive carbon is approximately in prolongation with that of the negative. The next step is to align them accurately and, in order to do this, the positive carbon holder is provided with adjustments in two planes: the tangent screw E, Fig. 2, gives a right to left motion and the eccentric pin D gives an up and down motion. Make sure that the carbons are clamped securely so that elevating the drum will not cause them to come out of alignment and, also, in securing the carbons in position, observe that sufficient play is left for the arc stream to be drawn to normal length after starting, *i.e.* give enough play so that the carbon tips may be separated about three quarters of an inch. Finally, bring the carbon tips approximately in the focus by means of the focusing screw O, Fig. 2; a line will be found inside the drum by which the focus may be located (*i.e.* in most projectors).

(b) When starting with a set of carbons partly burned, unless the crater is evenly formed, break it off and ream out a new one, but otherwise than this proceed as in (a).

(c) When the arc stream breaks, *i.e.* light goes out, for any cause, proceed as given in "Second".

Second

Feed the carbons together by turning the feed screw until they nearly touch and then turn on current.

If the circuit breaker goes just after starting, such being likely only in cases when the generator is over-compound, open lamp switch and start over with the generator at a voltage low enough, but if the voltage of generator cannot be lowered on account of other loads, the necessary resistance must be inserted with a line rheostat. If the circuit breaker still goes examine the starting mechanism, however trouble with the latter is unlikely.

Third

Keep the current as near normal as possible for this assists the crater in forming properly.

Fourth

After the lamp is operated long enough for all parts to reach their normal temperature and the arc has become normal, run

the carbons apart slightly and note the voltmeter reading at the first stroke of the magnet; if the voltage is above normal loosen and if below tighten the feed spring U, Fig. 2, until proper adjustment is made. The adjustment of the feed spring, however, should be done only when the lamp is in a horizontal position, when it is obvious that there is no sluggishness in motion due to friction, and when the carbons are burning properly. It is poor practice to tamper frequently with the feed spring, in fact the only adjustment which is theoretically necessary is to tighten occasionally to compensate for relaxation of tension that occurs from long use.

Observe that the pawl engages properly in the ratchet wheel. The feeding together of the carbons, *i.e.* the angular distance through which the pawl draws the ratchet wheel, per stroke of magnet, is regulated by the adjusting screw R, Fig. 2, *i.e.* knock off screw, Fig. 6. A low rate of feeding is better than a high rate.

Fifth

Focus the lamp approximately by noting the position of the crater on the ground glass L, Fig. 17, (none on 60 inch) or by noting the parallellism of the rays with the eye. Though it is probable that some searchlight attendants can focus the beam accurately themselves without assistance, the writer believes, in general, it should be done as outlined in Chapter V.

MAINTAINING THE ARC

To maintain the proper arc the attendant has to give the lamp judicious assistance. In some cases the lamp will maintain the normal arc automatically but there are cases where assistance is necessary, and it is the same here as with other devices, too much adjusting is worse than neglect.

First

Keep the current as near as possible to its normal value. By keeping the current near normal the crater forms evenly and the carbons tend to burn quietly without developing undesirable arc characteristics. If this regulation cannot be done within the limits of the line rheostat, make the necessary adjustments with the generator's field rheostat, i. e. keep the generator voltage suitable. The question of regulating the current automatically is taken up under Power Supply.

Second

Keep the length of the arc stream proper.

If the arc is suitable, *i.e.* burning quietly, and the current

normal, the lamp mechanism will usually maintain the proper length automatically. However, if the mechanism feeds at an incorrect voltage and the trouble cannot be remedied conveniently, maintain it correct by hand control. But bear in mind that the mechanism should be kept in adjustment so that normally this auxiliary is unnecessary.

Third

Pay close attention to the focussing of the beam and if at any time it appears to be poorly focussed report the fact to the person at the controller.

Fourth

Keep the arc stream centered so that the crater will form uniformly, for, if the crater burns to one side, it usually develops a raggedness which causes the current to fluctuate. On this point the writer's experience has been that a proper alignment prior to starting avoids usually any further adjustment.

Adjustments after the arc is burning can only be made with difficulty. To begin with, the position of the person operating the adjusting screws prevents him from judging the alignment; however it may be done approximately by having a person observe through the peep sight and direct the motion given the crater; the degree of up and down motion may be fairly well judged but the degree of right and left motion is the merest approximation.

Whatever shifting is done to recenter the arc stream should be by small increments. It is well to err on the side of too little than too great a change in adjustment.

ARC TROUBLES

Various arc troubles arise and to accomplish anything towards preventing or checking them the attendant must keep familiar at all times with the condition of the arc. Comparatively little can be done towards checking arc troubles once they get a start, but much can be done towards preventing them; the old adage is *apropos* here that "an ounce of prevention is worth a pound of cure."

Some experience is necessary to tell if the arc is burning normally or to determine if trouble is ahead and the only evidences to be relied upon are: the appearance of the arc through the peep sight and the ammeter and voltmeter readings.

If the arc is proper, it should appear with the arc stream well centered in an evenly formed crater and the instruments should show the current and voltage steadily and simultaneously at or

near their normal values, *i.e.* the values for which the lamp is designed.

Due to various causes the arc will tend at times to become abnormal and if such development is not prevented bad arc characteristics appear. Among these may be mentioned:

(1) Arc stream running off center.
(2) Crater burning unevenly or raggedly.
(3) Hissing, roaring and other noises.
(4) Shooting flames.
(5) Formation of mushrooms.

Bad arc characteristics are attended usually by fluctuations of current. The fluctuations are due to instability of the arc stream caused mostly by unevenness or raggedness of the crater; the stream tends to take a path of the shortest distance between the carbons, thus the current will concentrate at any protruding part of the crater; the heat will burn this protrusion and the stream will thereupon jump to another one and so on; and, in consequence of such shifting, the arc resistance varies widely, causing a fluctuating current. Sometimes the stream jumps all around the crater and at other times it may jump out altogether. The latter is especially serious on account of the time lost in starting the arc again. Each fluctuation of the current causes a flicker in the light. Serious fluctuations cause the beam to flicker so badly that it is useless.

A condition which promotes instability is improper protection from the wind. Perhaps it would be a good idea to equip searchlights with a damper to control the draught, for many of them are exposed to high winds. The writer's observations have been that a heavy fluctuating draught such as the arc frequently gets in practice contributes largely towards instability; in fact the arc stream is sometimes "blown out" completely.[1]

Raggedness or unevenness in formation of the crater is usually produced by the arc stream burning off center due to poor original alignment or due to the carbons coming out of alignment on account of not being properly secured. A lack of homogeneity in the construction of the carbons may produce the same effect, however the writer believes the causes to be more frequently those mentioned.

In addition to causing a fluctuating current an unstable arc is attended by shooting flames, or hissing, or roaring noises. A steady flame is an evil unavoidable and attendant to most carbons; it seems to be due to some substance used in the binding material which is necessary to make the carbon adhere properly. It often

happens, however, that the arc makes peculiar noises, but, notwithstanding, a very good beam may be obtained.

The formation of mushrooms is an evil which occurs rarely with a 60-inch light. When a mushroom forms, it can sometimes be shaken off by tapping the carbon gently.

STARTING MECHANISM

As a general rule the starting mechanism gives little trouble. It simply starts the arc and as long as the arc current flows the magnet remains in its attracted position. When the current ceases, a spring returns the magnet to a position ready for "striking"* the arc, *i.e.* pulls the carbons apart through a distance equal to the striking distance.

In some instances the starting mechanism has failed to return the carbons to the striking position, the consequence being that when the current was turned on, and the carbons brought in contact, the circuit breaker would go. This trouble may be due to the mechanism being out of order, or, if the drum is elevated, due to gravity setting up a moment too great for the spring to overcome. In any case the arc may be struck by running the carbons together until they touch either automatically, or by hand, and then separating them by turning the feed screw rapidly. However such a makeshift should be resorted to in an emergency only.

A slight trouble will occur in starting because the starting magnet draws the arc stream to a length below normal. In a short time however the abnormal length is adjusted by the burn-away of the carbons. To remedy the trouble quickly the stream may be brought to normal by running the carbons apart; to do this it is sometimes necessary to lift the pawl off the ratchet wheel.

THE FEED MECHANISM

The feed mechanism brings the carbons together whenever a certain voltage across the arc is exceeded, this voltage being determined by the initial tension given the feed magnet spring. In the factory the spring is carefully adjusted before the lamp is shipped so that the feeding voltage will be normal, however there are certain factors which enter causing an incorrect feeding voltage. They are chiefly the following:

(1) Due to use or accident there is a relaxation or decrease in tension of the spring which lessens the feeding voltage. This

* "Striking" is a term in searchlight practice applied to a certain part of the formation of an arc. It is the action of drawing the arc stream after the carbons touch.

may be remedied by tightening the spring by means of the spring adjusting screw.

(2) Friction of the moving parts causes sluggishness in motion and increases the feeding voltage; the most common cause here is rust or carbon dust getting into the lubricating oil. In order to avoid such trouble the lamp should be frequently cleaned and oiled.

(3) The resistance of the feed magnet coil is increased by the heat consequently the feeding occurs a few volts higher at the start than after the coil takes its normal temperature. In order to adjust the mechanism properly no change in the tension of the spring should be made until all parts bave reached their normal temperature.

(4) When the lamp is moved out of a horizontal plane a moment due to gravity, changes the feeding voltage by a few volts. In the latest type of lamp this fault is remedied by putting the armature pivot parallel to the longer axis of the lamp.

It may appear from what has been said that serious troubles may arise due to the features cited but this is not the case, in fact it is seldom that the mechanism cannot be made to feed automatically at within two or three volts of the required amount; and, if for any reason the automatic feeding fails, the proper length may be maintained by hand. However the automatic mechanism performs this function best and it is poor practice for the attendant to rely on hand feeding except to bridge over an emergency.

In the mechanism the ratio of the gear wheels on each feed screw is approximately such that the crater is kept automatically in the focus of the mirror after first adjustment. This ratio is determined from the average performance of a number of sets of carbons. It is therefore at times that the crater may burn out of focus, making it necessary to refocus the beam; however practice seems to show that one focussing in the start is usually sufficient during the life of a set of carbons.

ELECTRIC CONTROL MECHANISM

The chief sources of trouble here are open circuits, incorrect voltage for motors, and friction in bearings of moving parts.

The cause for open circuits are various. Moisture and oil are among the chief ones since they deteriorate the insulation, in consequence of which the wires short circuit and burn; there have been cases of this in the motor and clutch electromagnet fields. As a telephone is always at hand at a searchlight, a convenient

means of locating open circuits is by breaking the primary telephone circuit and closing it through the circuit in question; if there is an open circuit it will be indicated by the absence of the "click" in the telephone receiver at the "make and break."

Incorrect voltage for the training motors gives wrong speeds and consequently unreliable training of the beam. The 36-inch requires 100 and the 60-inch 115 volts for their training motors.

Friction in the moving parts causes sluggishness in the training and in extreme cases serious damage may be done the motors because overloads cause sparking, or possibly may do serious damage to the armature. All bearing surfaces should be kept clean and well oiled.

MISCELLANEOUS

The obturator shutters in the past have proved a frequent source of trouble, the brass ones burn up and the asbestos ones are easily broken. Those made of graphite are better both in pattern and material and will perhaps give little if any trouble. If the shutters burn up others may be improvised. Brass or asbestos is good material for them.

From time to time the lamp should be removed from the drum, cleaned, and the bearing surfaces well oiled. In oiling care must be observed that the oil does not flood, for it damages the insulation and it also catches the carbon dust which may cause sluggishness in the motion of parts. In taking the lamp out never lift by catching the carbon supports as very slight bending will get them out of alignment.

Carbons should be kept in a clean dry place and free from grease, water and other impurities. If carbons have been exposed to such, it is good practice to bake them prior to using. The oven in the bake shop or a flue in a boiler, is a good place for this purpose.

In recarboning a lamp the question of time is important. It can easily be done in two or three minutes with a little practice, but care must be observed that the carbons are secure and properly aligned. It is of great importance, however, that the drum be turned so that the least amount of wind strikes the mirror, as sudden cooling may crack it.

The mirror should be kept dry, otherwise it will spot or frost. Prior to using it should always be cleaned; in doing this, dust the mirror with a soft brush or soft cloth and then clean with a piece of chamois skin, but be careful in wiping that no grit is present to scratch the mirror. The importance of cleanliness here is great

because any dirt or dust will reduce the amount of reflected light. It is stated* that rays of sunlight may damage a mirror and therefore such exposure should be avoided.

In elevating the lamp care should be observed that the position of the arc does not endanger the mirror since hot particles from the crater falling on the mirror may damage it. The person at the controller should observe this precaution and should not give the beam a greater elevation than about 35°; however the searchlight attendant is directly responsible for such damage for he should stop the motion of the drum, when the mirror is endangered.

Should the lamp go out due to the circuit breaker going, *open the lamp switch immediately*. This precaution is necessary to avoid any danger of blowing the fuses at the power house when the dynamo attendant returns the circuit breaker. In order to indicate to the searchlight attendant when the circuit breaker has opened a pilot lamp should be placed across the lamp cable terminals. The blowing of the fuzes is a serious matter on account of the time it takes to put in new ones.

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* See Wallings Electrical Installations of the U. S. Navy, page 73.

CHAPTER V.

THE BEAM

FOCUSSING THE BEAM

The angle made by a reflected ray of light with the normal to the reflecting surface is equal to that made by the incident ray; hence, by using a parabolic reflecting surface (and assuming the light to emanate from a point), we have for the positions of the source of light:

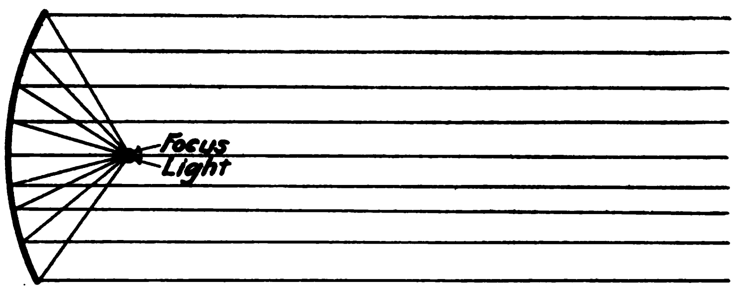


Fig. 46. Point of light and focus coincident.

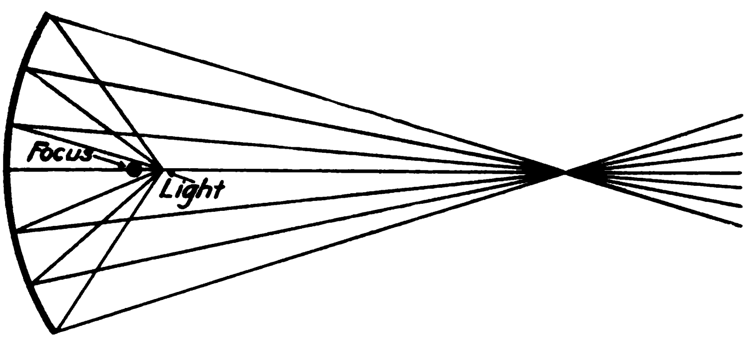


Fig. 47. Point of light beyond focus.

(1) When at the focus, the reflected rays are parallel. See Fig. 46.

(2) When beyond the focus, the reflected rays converge. See Fig. 47.

(3) When between the focus and the mirror, the rays diverge. See Fig. 48.

In a searchlight, the light emanates from a circular surface.* Hence, when the crater is at the focus, light reaches the mirror from all parts of its luminous area and each ray is reflected

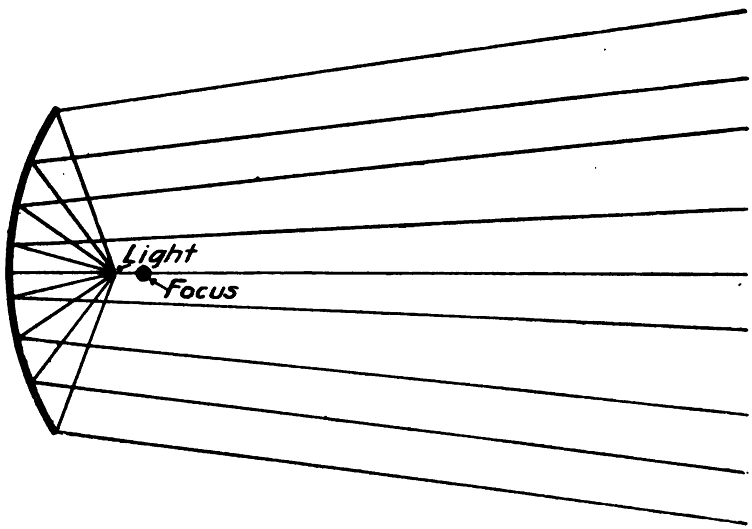


Fig. 48. Point of light between focus and mirror.

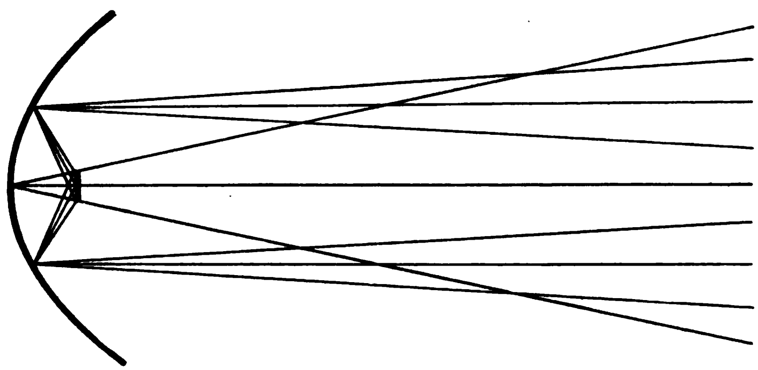


Fig. 49. Effect of light at focus when emanating from a circular area.

according to its angle of incidence; thus the crater forms a base for numerous cones of direct rays, whose vertices are points on the mirror, these points being also vertices of cones of reflected rays whose axes are parallel to the mirror axis. See Fig. 49.

* The diameter of the crater in the 60-inch light is about one inch.

Consequently, in a searchlight the total effect of the reflected rays is to give a beam whose outline is somewhat like the one in Fig. 50. In Figs. 49 and 50 matters are exaggerated for illustration. In reality the rays are sensibly parallel, except when the observer is directly behind the light.

Hence, in a similar manner to what is represented by Figs. 46, 47, and 48, the position of the crater may cause a sensibly parallel, a converging, or a diverging beam.

When the rays of a beam are sensibly parallel, the beam is said to be concentrated.* The present practice is to use only the concentrated beam.

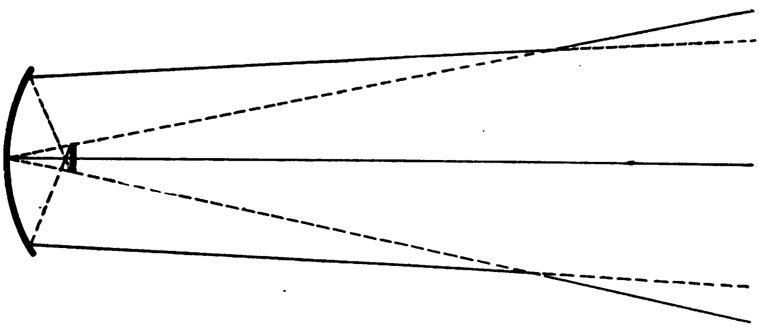


Fig. 50. Sketch showing outline (exaggerated) of a searchlight beam when focused.

Focussing the beam is getting the crater in the focus. The position of the crater is changed relatively to the focus by turning the focussing screw, O, Fig. 17, which engages in a nut on the lamp frame; this moves the lamp frame on its guides and the arc may be given a backward or forward motion. Focussing must be done while the lamp is burning. It will assist matters in starting, however, if the carbon tips are placed approximately in focus before turning on the current.

Some searchlight attendants can focus the beam by observing its appearance. However, one is handicapped, because in this position it is difficult to determine the extent of the divergence or convergence.

Another method is for the attendant to focus by observing the position of the crater on the vertical peep-sight. See Fig. 17. All except the 60-inch have the peep-sight. It is nothing other

* In some searchlights the glass strips in the front door are cut so that each is a plano-convex lens with the convex side outward in order to produce a diverging beam. In the U. S. Coast Artillery, only the concentrated beam has been found satisfactory, therefore lenses are never used.

than a lens located in the upper part of the drum so that when the crater is in focus its image will be reflected on a piece of ground glass. The correct position of the image on the ground glass can be obtained as follows: Have someone in an observing station to one side of the light and in communication with the searchlight attendant and then put the beam on some distant object; and when the best position of the crater is settled upon, after several trials, the location of its image on the ground glass can be marked. Thereafter the focussing may be done by the searchlight attendant getting the image on the marked position.

Though neither of the above methods of focussing is very accurate, they possess the advantage that they are simple and can be quickly executed.

A method which is gaining popularity is for the searchlight attendant to do the focussing under the direction of the person at the controller, the latter judging with his eye and giving word for the beam to be diverged or contracted as the case may require. It is best to bring the beam up from the water and to a position where it may be viewed sidewise. This gives the beam a well defined outline, a better opportunity for judgment is afforded and somewhat fixed conditions are attained for the examination. The latter is important because certain positions of the beam relative to the observer cause it to appear diverged, though, in fact, the crater is in the focus. This is due, without doubt, to the spreading effect being noticeable, caused by the light not coming from a point. It has been the writer's experience with this method that the controller attendant, after a little practice, is able to bring his beam speedily to its properly focussed condition.

It may be remarked that it is important to have the beam properly focussed at all times for the illuminating power is greatly reduced by bad focussing. The focussing should be done carefully just prior to using the searchlight or just after recarboning and then left alone if possible, since the gear ratio of the feed mechanism is such in most cases that the crater is kept in the focus automatically. The remedy frequently applied to a searchlight trouble is "to focus the beam", and often it is simply valuable time wasted; for if the beam be properly focussed in the start there will be more than likely no further necessity of focussing during the life of the carbons.

SKILL IN USE OF THE BEAM

As has been said the beam is used as an adjunct to the gun and mine defense for searching and illuminating purposes.

The position of the beam relative to the object is controlled by moving the controller handle. There are four training speeds horizontally and two vertically in the new searchlight. In order to tell the speed used the operator has to note the angular velocity of the beam, or the angle through which the controller handle is moved, or both. In either method the matter is slightly difficult. It is comparatively easy to distinguish the difference between the two vertical speeds and between slow and fast horizontal speeds, but it is hard to distinguish between the two slow horizontal speeds. In tracking a vessel these speeds, i.e. first and second horizontal speeds, are used chiefly.

It is certainly very important that the person at the controller be thoroughly familiar with the speeds and be able to handle the beam effectively. Some difficulty arises in following a vessel at long range. In most cases the vessel moves slower than the first speed, but this may be overcome by giving the beam the necessary succession of movements which is done by repeatedly pushing the controller handle to the first speed and releasing it quickly. In trying this a novice will likely give the beam an unsatisfactory "jumping," nevertheless with a little practice the jumping appearance may be eliminated to such an extent that the motion by increments is unnoticeable.

It is evident the object's visibility will be best to the observer when his line of sight passes through as little as possible of the beam itself; therefore the general rule to be followed is *to keep the object in the edge of the beam nearest the observers.*

The person at the controller, at least, must see the object at all times but he must use the beam so that if possible all observers using the light will see the object in addition, and yet not blanket the view of observers using other lights on other objects. Without question he should be equipped with a high grade telescope conveniently mounted on a pedestal and pivoted for vertical and horizontal motion.

Using the beam effectively for short distances is not very difficult. If the light's elevation is high, allow the beam to intersect the water near the field of search; the beam being cylindrical and the angle of incidence small in the direction of the beam, a flat elliptical area is illuminated; bring this on the object and in any part of it the object will usually be visible; the blanketing in this case will occur just at the intersection of the beam and the water, which is usually not very serious. If the elevation is low, hold the beam just above or so the lower edge cuts the object; in

this case the blanketing may occur for the entire length of the beam which is often a serious matter.

Using the beam effectively for long distances is more of a problem on account of the difficulty in getting the proper visibility. In this case, also, the blanketing effect is largely reduced by giving the light a high elevation.

When the observers are below the position of the light and on both sides, it is best to use the under edge on the object as this will give all the observers a view of the object in the edge.

When the observers are all on one side of the light, the side edge nearest them is the best. To use the side edge bring the beam on the water near the field of search, the ellipse cut out by the intersection is very oblong in the direction of the beam which gives the observers a long side edge whose outline has the appearance of a dark line; sweep this line over the area of search and when a vessel is picked up bring the edge of the beam on the bow or whatever part of the vessel it is desired to illuminate. It seems that one part of the side edge is sometimes better than the other since the intensity of the light is not always uniform. This is a matter dependent upon the burning of the carbons and cannot be governed by any rule. It is therefore well to try the different parts and use that which gives the best illumination.

Whenever the location of the observers permits it, other things being equal, the side edge without question gives the longest range of visibility. It seems that there is less interference with the line of sight and furthermore the contrast between the object in the edge of the beam and the blackness in close proximity helps the eye in outlining the object. In using the under edge the visibility is not so good because the contrast is poorer on account of the reflection of the beam on the water. However there are many places where the side edge, though better for some of the observers, blankets others.

To use the beam one must practice with it considerably. It is a mistake to think that anybody can operate the controller of a searchlight; in the first place it is a most difficult matter to get the beam perfectly under control so that at any instant the beam can be moved in either direction at the desired speed; it is also very difficult to attain the proper skill in using the position of the beam successfully relative to a vessel; furthermore, the person at the controller should know how to focus the beam and to tell when the arc is failing to give the proper light, in other words, for him to be efficient he should have a thorough knowledge of everything connected with his searchlight. In addition to the above,

he should have authority over those connected with the immediate operation of the light and should have the means for communication with both the power house and searchlight.

As has been said there are these things to be looked after, the proper burning of the arc and the focussing, and the use of the beam; they must be kept up to their maximum efficiency simultaneously. Any departure from this will reduce the usefulness of the light enormously, and it is the person at the controller who should have the responsibility for and the authority to maintain these conditions.

RANGE OF THE BEAM

Assuming the arc to be normal and the beam properly used and focussed, the range at which an object may be properly illuminated to be visible to the observer depends upon:

(1) The condition of the atmosphere.
(2) The color, nature and extent of the exposed surface.
(3) The distance between the light and the object, and the distance of the observer and his position relative to the light and object.

ATMOSPHERE

Though the rays in the beam appear parallel, they diverge; for example—at the light the beam's diameter is 5 feet, while at 2,000 yards it is about 200 feet. For this reason the intensity of the illumination of an object falls off as its distance increases. It is sometimes stated that the intensity falls off as the square of the distance, due to this divergence. However, this does not appear possible, because, for the law of inverse squares to hold, the rays must be distributed uniformly and those in question radiate from the same point, neither of which occurs in this case, and, furthermore, the tendency of the reflector is to bring them parallel.

It is a fact, however, that the illumination falls off immensely with the distance. Except for a relatively slight falling off due to divergence, the cause is atmospheric absorption. But short experience with searchlights brings to one's notice the atmosphere's effect on the range. The writer performed some experiments in an effort to get some data on this question. Though the tests were extensive, nothing was deduced other than a few facts quite well known. In brief they were that—

(1) Fog, smoke, snow or rain may reduce the penetrating power of the beam to a useless range.

(2) Haziness when produced by fine rain, mist or very light snow reduces the penetration considerably; however, objects may be made visible for short ranges.

(3) Slight haziness, when produced by smoke or dust, is more destructive to the penetration than if the same appearing haziness were produced by moisture alone: in fact such may make the beam quite useless.

EXPOSED SURFACE OF TARGETS

The nature and color of target play a very important part in the effective range. At the Army and Navy maneuvers in 1903,* the battleships were painted white and they were usually picked picked up at 9,000 and 10,000 yards; the destroyers "though dark were painted with some form of luminous paint" which "shown almost as clearly as if painted white," and they were also picked up readily; but the tug boat "Cora" painted a dull black was picked up with difficulty. At the Army and Navy Exercises in 1905 the effect of the color of the target was again brought out.

"On one occasion,† the Texas, painted white, was picked up at 8,000 yards, while the Hartford, painted black, was not seen until she approached to 5,100 yards."

The extent of the surface exposed to the beam is a matter of importance; for example, it makes a difference in the range whether the boat is being observed broadside or bow on.

POSITION OF THE OBSERVER

The nearer the observer to the object the better is the visibility and vice versa, the distance between the light and object being fixed. Again, the observer should be where he looks through a small amount of beam. For this reason searchlights should be elevated and the controller located to one side. But the distance between the searchlight and controller is limited because, if too great, the observer cannot detect with any degree of accuracy motions of the beam for the slow training speeds, and, furthermore, in certain conditions of the atmosphere the beam is not visible to him.

Nature of environment makes a difference in the visibility of the object, for the eye is either helped or retarded in outlining an object by the contrast offered. For example, on a dark night the object is visible better than on a moonlight night. Again, if the object is in the side edge of the beam nearest the observers,

* See Captain Jackson's report.
† See Artillery Memoranda No. 6.

the visibility is better because the blackness in close proximity makes a good contrast.

RANGES FOR VISIBILITY

There are, perhaps, three important ranges for the observer when the object is visible: in one the target appears a sort of luminous spot, in another the target may be identified, and in the third it may be waterlined.

For a 60-inch light, *the maximum ranges* for a white painted battleship under favorable conditions are not greater than:

11,000 yards for the luminous spot range,
9,000 yards for the identification range,
6,000 yards for the waterlining range.

The above appear to be fair estimates. However, better results have been attained.

At Portland during the maneuvers, battleships painted white were picked up at 13,000 yards on several occasions. In tests* made at Nuremberg, Germany, with a 60-inch, at 150 amperes and with the beam on light colored buildings, an effective range of 10,940 was obtained. At Ismid under similar conditions 17,775 yards was obtained.

For a 60-inch (200 amperes), the ranges obtained under the usual conditions met with in practice rarely exceed:

8,000 yards for the luminous spot range,
6,000 yards for the identification range,
4,000 yards for the waterlining range.

The range of a 36-inch light is slightly less than two-thirds of that for a 60-inch.

* See page 18, Light Projectors, by F. Nerz; translation by Captain Schultz.

CHAPTER VI.

POWER SUPPLY

A searchlight requires power for the electric control mechanism and lamp. For both direct current is necessary. The alternating current arc is not applicable to searchlight purposes and direct current is more suitable for the electric control.

POWER FOR ELECTRIC CONTROL

It is a simple matter, comparatively, to supply this power, since the motors and relay apparatus require constant potential, the latter being designed for the same voltage as the motors. On the 36-inch projectors the motors are for 100 volts and on the 60-inch for 115 volts. Both for proper training and good treatment, the voltage should not vary considerably from the rated value: that is, a good voltage regulation at the motor terminals is required.

The methods for power supply are:—

(1) Running separate leads from the generator supplying power to the lamp.

(2) Using a separate source of power.

(3) Making connections at the terminals of the lamp conductors.

The first is satisfactory where the generator voltage furnishes suitable value and the resistance of the leads is not so high as to subject the motors to an abnormal voltage variation.

The second method is perhaps the best, since at present most of the generators for the lights are small over-compound machines. A separate source of power is required if the lamp is supplied from a constant current generator.

The third method can be used only when the lamp is operated from a constant potential generator with a resistance in the lamp circuit. One objection to this method is that the lamp current varies, due to several causes, and this makes the potential at the lamp feeders variable, the extent of the variation depending on the amount of resistance in the lamp cable. However, this method is objectionable otherwise. To secure the proper voltage

at the feeder terminals, the line rheostat must give considerable drop, and if there is some distance between the projector and the powerhouse, a condition often arising, the lamp cable must have large cross-section and the generator a high voltage. For example, take the case illustrated by Fig. 51. Here the length of the cable is about 700 feet. With the connection at B, for normal conditions (arc proper and 200 amperes flowing) we would have 65 volts across the arc, and say 40 volts across the rheostat terminals, giving 105* volts at the feeder terminals, and this

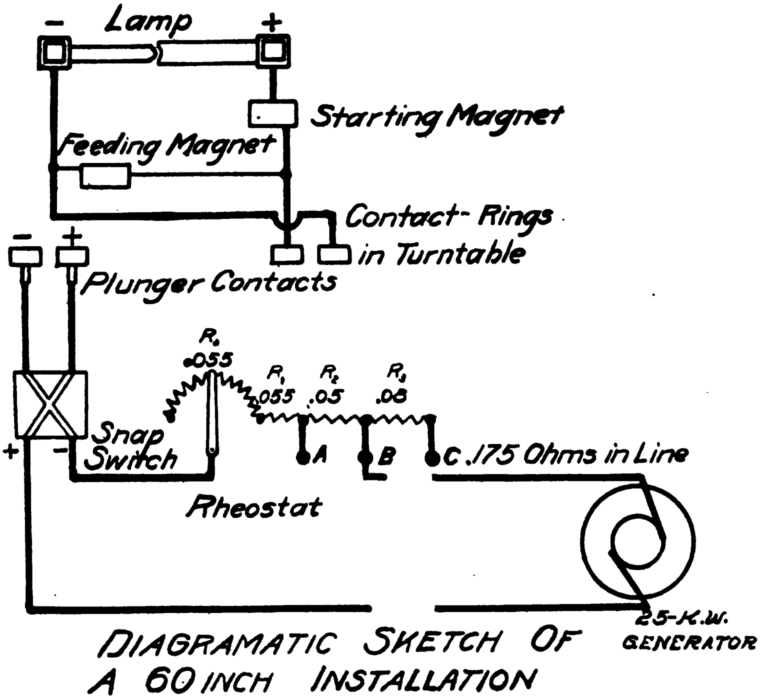


Fig. 51.

would require a generator voltage of 145 volts. The generator voltage when the lamp goes out depends on its characteristic, but assume a flat one; then should this happen for any cause, the motors would get a voltage of about 140 volts, that is, our motors would be subject to a 30 per cent. voltage variation.

Again, in order to make the voltage variation at the feeder terminals within the limits while lamp is burning, we are forced to

* Which is, in fact, 10 volts below the rated motor voltage. In this installation service was so poor, when the control power was taken at the lamp feeders, that it was abandoned; thereafter power was taken from a storage battery circuit.

use large cross-sectioned conductors, whose expense is excessive for the results; whereas, without attempting to get the power at this point, we could use smaller cross-sectioned conductors and have them such that they give the desired resistance* for the lamp regulation, thus doing away with the fixed resistance in the rheostat. This would give a saving in first cost all around, as well as a saving in power, for the generators in most cases could be run at lower voltages.

Though the third method is at present in general disfavor with every one, it was at one time generally installed and will be found in use in several fortifications.

POWER FOR THE LAMP

To supply power for the lamp is a problem more difficult, as the arc should have approximately constant current. The light is due to the high temperature of carbon at its boiling point, this boiling occurring over the surface of the positive carbon, causing the crater, the light itself being emitted from an incandescent film over it, whose area is proportional to the current. The stream's stability also is dependable on the current because, other things being equal, the rate of generation of material for it is proportional to the current. The writer has performed some experiments on arcs carrying large currents and he feels convinced that a steady current is the first consideration towards obtaining stability. That we need a stable arc for searchlight work no one will gainsay.

The following two systems may be used to supply power and these, to a more or less degree, give a constant current:—

(1) Constant potential generators with fixed resistance in series with the lamp.

(2) Specially designed generators which by their own regulation give a constant current.

CONSTANT POTENTIAL GENERATORS WITH A FIXED† RESISTANCE

Here we have the method found commonly in practice, the only exception being the installations on the portable sets. The effect of this resistance is to give a sloping characteristic at the lamp terminals (see Fig. 56) and the more of it the steeper the slope; that is, as we increase this resistance the less the change

* This refers to the constant potential generator system.
† Often referred to as "ballast".

which can occur in the current for a given change in the arc's resistance. Thus we get a condition at the lamp something near that produced by a constant current generator.

It is obviously better for the generator itself to have a drooping characteristic. A shunt generator is better, therefore, than a compound one. But in this system a high voltage at the generator is often necessary, and for this and other reasons compound machines have been installed entirely.

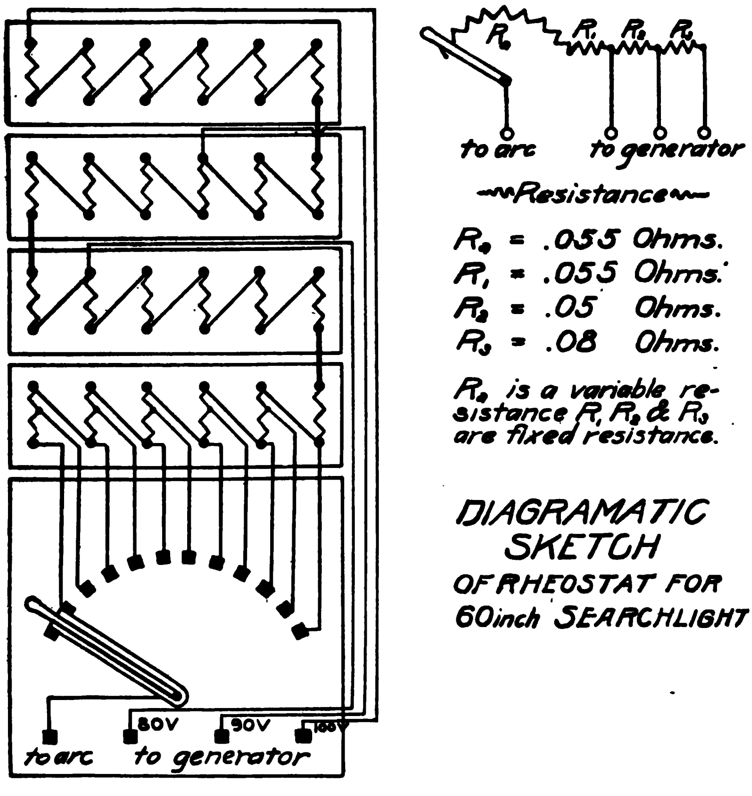


Fig. 52.

The resistance in series with the lamp may be in the cable, in a rheostat or in both.

Rheostats vary in general appearance, but all are constructed similarly, consisting of a fixed and variable section of resistance. (See sketch in Fig. 52.) The variable section is for adjustment of the current when it becomes noticeably abnormal, it being important that the attendant keep the current

approximately normal. The fixed section is for any of the following purposes:—

(1) To supply resistance in addition to that in the cable to give a sloping lamp characteristic.

(2) To secure the necessary voltage drop, which is not caused by the feed cables, so that the lamp may be operative from a given powerhouse voltage.

(3) To furnish proper voltage at the terminals of the feed cables so power for the electric control may be had there.

To make the rheostat adjustable to several lengths of cable, the fixed section is divided into three or four parts.

It is sometimes misunderstood as to what extent the lamp contributes to the regulation of the current.

Before taking up this question, let us examine the action of the lamp. It will be remembered that when current is turned on, the feeding mechanism brings the carbons together until they touch and the starting mechanism strikes the arc; and thereafter, as the carbons burn away the feed mechanism closes them together, compensating for the loss and keeping the arc in the focus, the feeding depending upon changes in the current produced by changes in length of the arc stream, provided sufficient resistance is in series with the lamp and the mechanism is in adjustment. The necessity of the series resistance will be understood from the following: First, suppose a constant potential generator connected across the lamp terminals, *i.e.*, across the arc; it is evident that the mechanism would not feed whatever the length of the arc, because there could be no change in potential. But suppose the generator had a voltage V_g and in series with it is connected a resistance R_1 and the lamp whose voltage drop across the terminals is V_a, then

$$V_a = V_g - CR_1$$

Since V_g and R_1 are practically constants, we have the voltage supplied the lamp is a function of the current, the current changing in value due to changes in the arc's resistance. The latter is proportional to the arc's length (among others things). Now, it can be proved that the greater the value of R_1 the less change in the current will be required to produce a given change in voltage across the lamp terminals: in other words, the bigger R , *i.e.*, the more nearly the current is to constant, the more sensitive will be the feeding. In practice, however, the feeding is sufficiently sensitive if the resistance in series with the lamp is enough to cause about 30 volts drop for the 36-inch and about

35 volts for the 60-inch. For example: the 60-inch lamp may be operated on a constant potential generator if the line drop is 35 volts, the latter being either in the cable or in the rheostat, or both.

Bearing the lamp mechanism in mind, it may be seen that the current is regulated only to the following extent: if the stream lengthens (say due to carbons burning away), or if the stream otherwise increases in resistance, the current falls and this raises the potential difference at the lamp terminals, causing the feed mechanism to act, feeding the carbons together until normal conditions are established. But this adjustment is slow, being step by step, and does not take care of tendencies of the current to fluctuate.

It must be borne in mind, too, that the stream is a liquid conductor whose resistance is inversely proportional to the current; that is, if we increase the current we volatilize more material, which, among other things, gives a larger cross-section, hence less resistance; and if we decrease the current, vice versa. A shift in current, therefore, gets an additive value, the result being that an unstable condition readily develops.

Over this tendency of current variations there is no control, either by the lamp mechanism or the generator regulation. This state of affairs is most unfortunate, because an unstable arc is disastrous in searchlight work, each jump of the current making a flicker in the beam, and, as we know, a flickering beam is worse than useless.

That defects in our system should appear is not surprising, for we have been using searchlights but a short time. However, when sufficient demand arises for certain results with electrical apparatus, designers begin to work on the problem, and until then only. It is this idea which prompts the writer to point out these defects.

Again, take the rheostat. It is a big bulky affair, weighing some five or six hundred pounds, representing not an insignificant investment of capital. With it one can do but little in adjusting the current, for the variable section (on the 60-inch size) allows the current to be changed through not exceeding 20 amperes. Now it is quite frequent that the current gets a far larger value than this from normal. Also, the power consumption, which is dead waste, is beyond what might be considered good engineering; it ranges from 40 to 70 per cent. of that consumed by the arc itself.

This system is open to the objection, furthermore, that the feeding being a question of voltage, an improper arc length is maintained if the current is abnormal. For example, taking an

extreme case, suppose the feeding were at 60 volts (the normal current for this is 130 amperes) and the current should come to 80 amperes,* the feeding would continue at 60 volts, giving an abnormal stream length which the wind might break at any time. An arc of 80 amperes should be of such length as to give 50 volts across it.

Finally, take the use of a compound generator. The writer has seen not a single exception in their use, the full load voltage being 10 to 15 per cent. higher than no load. Not only is the current regulation exceedingly poor, but it is often impossible to start the arc unless abnormal precautions are observed, because the over-compounding sets up an abnormal current which knocks the circuit-breaker. It will be remembered that the arc stream as struck is below normal, which is conducive to this. To avoid it, either the generator voltage must be lowered or extra resistance inserted in the line. Service would be improved slightly, therefore, if the compound windings were cut out entirely. (See Fig. 56 and a discussion of it on page 64.)

But with either shunt or compound generators we are faced with difficulties. In brief, we cannot get a stable arc or one with safe continuity. We know in practice the carbons get "stuck," either due to carelessness in operation or otherwise, causing the circuit breaker to go, and to start things going again takes three or four minutes. This has happened in critical moments of sufficiency to bring the matter forcibly to every one's attention.

We hear our searchlight troubles ascribed frequently to the carbons. "'Bad carbons'" is a byword in searchlight practice. One hears this as an excuse for every variety of trouble. Without question the carbons are to blame somewhat; however, the writer thinks to a small extent. If the current were kept constant with a good regulation, say 15 per cent, from normal to short-circuit, a flickering beam would become largely a thing of the past and, furthermore, we would get a *safe continuity*. It is better current regulation that we need, and it is along this line improvement should be sought.

Though the constant potential system has these objections, it has the advantage that standard types of machines are used and other loads may be carried on them. In carrying other loads, however, difficulty arises because these may be variable, causing disturbing voltage fluctuations. The loads likely to do this are motors and other searchlights. But under our conditions there

* Due, we will say, to lack of boiler pressure. This sometimes occurs with the small boilers in use.

are few instances where it is necessary to carry other loads; in fact, it is usual to have a separate generator for each searchlight.

CONSTANT CURRENT SYSTEM

Though this system has been advocated by some, the idea of actually using constant current machines for our searchlights is of recent development and has not as yet taken any definite shape. However, considerable interest has been aroused on account of the introduction to this country of a generator designed by Dr. E. Rosenberg of Germany.

The nearest approach heretofore has been the differential generator designed for the portable sets. This machine gives a fair current regulation and in the absence of a better one might answer, its characteristic being more drooping than a shunt machine's. There are two field coils, one separately and the other series excited. These fields are opposite in polarity, hence the name differential generator. For the portable sets, a small constant potential generator supplies the separately excited field. The characteristic droops sufficiently so that the lamp series resistance is unnecessary; in fact, the generator may be connected across the lamp terminals. In addition to better current regulation the heavy rheostat was avoided, a considerable item for a portable plant. The writer observed this machine in operation two or three times and, during the periods of observation, the arc performance was quite satisfactory. This generator has not been tested thoroughly under service conditions, however it gives promise of good results.

But the Rosenberg* generator furnishes current with a closer regulation. The inventor claims that, from normal to short-circuit, the current can be kept to within 20 per cent. or even 10 per cent. of normal.

In this machine the current is regulated by armature reaction; when the current tends to go up armature reaction reduces the the voltage, bringing the current back near its former value; and the closeness of the regulation depends on the design of the machine.

In general appearance there is a similarity to the usual constant potential generator, but the design is very different.

* There are other designs besides the constant current type for searchlights. For this and other information on the Rosenberg generator, see the General Electric Review for December, 1907, and Captain Shipton's translation of Dr. Rosenberg's article.

Fig. 53 shows a sketch of a self-excited machine, for simplicity a bipolar being given: s s are brushes placed at the usual positions and are short-circuited, and M M are main brushes which carry the lamp current, these being placed 90 degrees from the others. The pole pieces are niched so as to make weak fields for commutation.

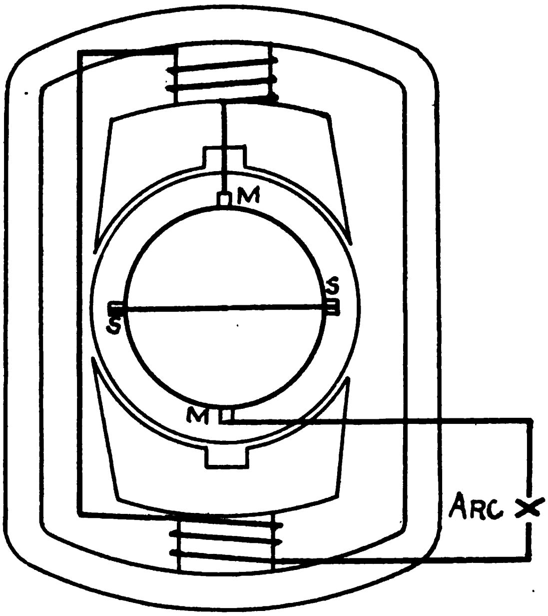


Fig. 53.

This arrangement of connections gives three separate magnetomotive forces: (1) a magnetomotive force due to the ampere turns on the poles, whose excitation is the arc current, which we will call F; (2) a magnetomotive force due to the ampere turns on the armature, whose excitation is the short-circuit current, which we will call S; (3) a magnetomotive force due to the ampere turns on the armature, whose excitation is the arc current, which we will call M. The relative directions of these magnetomotive forces are as indicated in the diagram (Fig. 54), their intensities being given roughly. That they are at right angles can be determined by an examination of the current direction of the coils in question. The flux producing the generator electromotive force, *i.e.*, at the brushes M M, is due to the resultant magnetomotive force, indicated in the diagram as R.

The cores of the pole pieces are small in cross-section so that saturation occurs at a relatively low current, in other words F

takes a constant value near normal current; and the pole shoes cover a large arc so that a strong back field M may be developed proportional to the current; this arrangement allows the generator electromotive force to vary in inverse proportion to the arc current.

That is, a tendency of the current to rise increases M (see Fig. 54), which reduces (F — M) and a reduction of (F — M) reduces in turn S, but both (F — M) and S are components of R, hence it is reduced also, which in turn causes the generator electromotive force to drop until normal current is reestablished. A tendency to decrease in current sets up a similar adjustment.

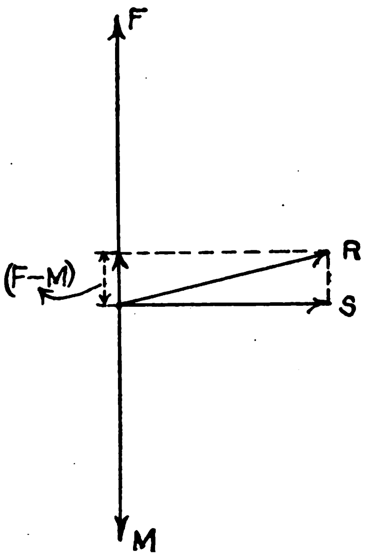


Fig. 54

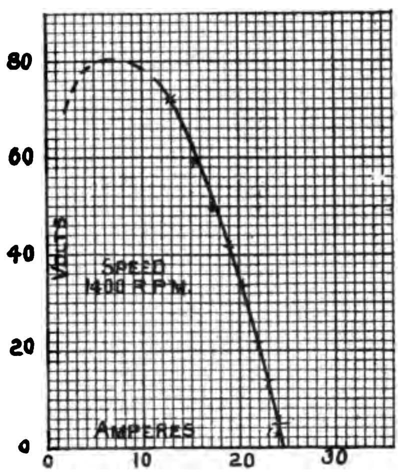


Fig. 55

When normal current flows in the main circuit, the short circuit takes a current whose value is about $\frac{3}{4}$ of this. But on somewhat less than normal current in the main circuit, the short circuit takes relatively more current. This is because the differential magnetomotive force (F — M) is larger in the second case, the current in the short circuit being due to its flux.

By observing the direction of R, whose flux produces the generator electromotive force, it may be seen that the location of the brushes M M is favorable to good commutation.

Fig. 55 gives the characteristic of a 1 K.W. self-excited machine which was used by the General Electric Company for demonstrations. While taking the data for this curve and subsequently while the machine was being exhibited to the writer, its performance was highly satisfactory. There was no sparking or

undue heating whatever. The machine can be guaranteed to keep within the usual temperature specifications.

By the use of a variable resistance in shunt with the series coils, the current can be adjusted as desired.

Considering Fig. 56, some idea may be obtained as to the lamp characteristics respectively when the generator is compound, shunt, or of the Rosenberg type. With a shunt or compound

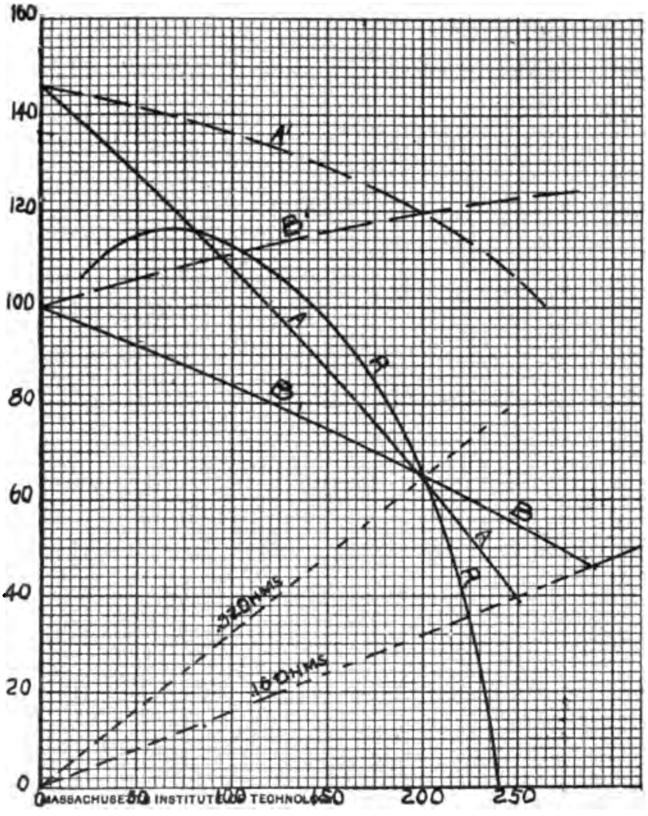


Fig. 56

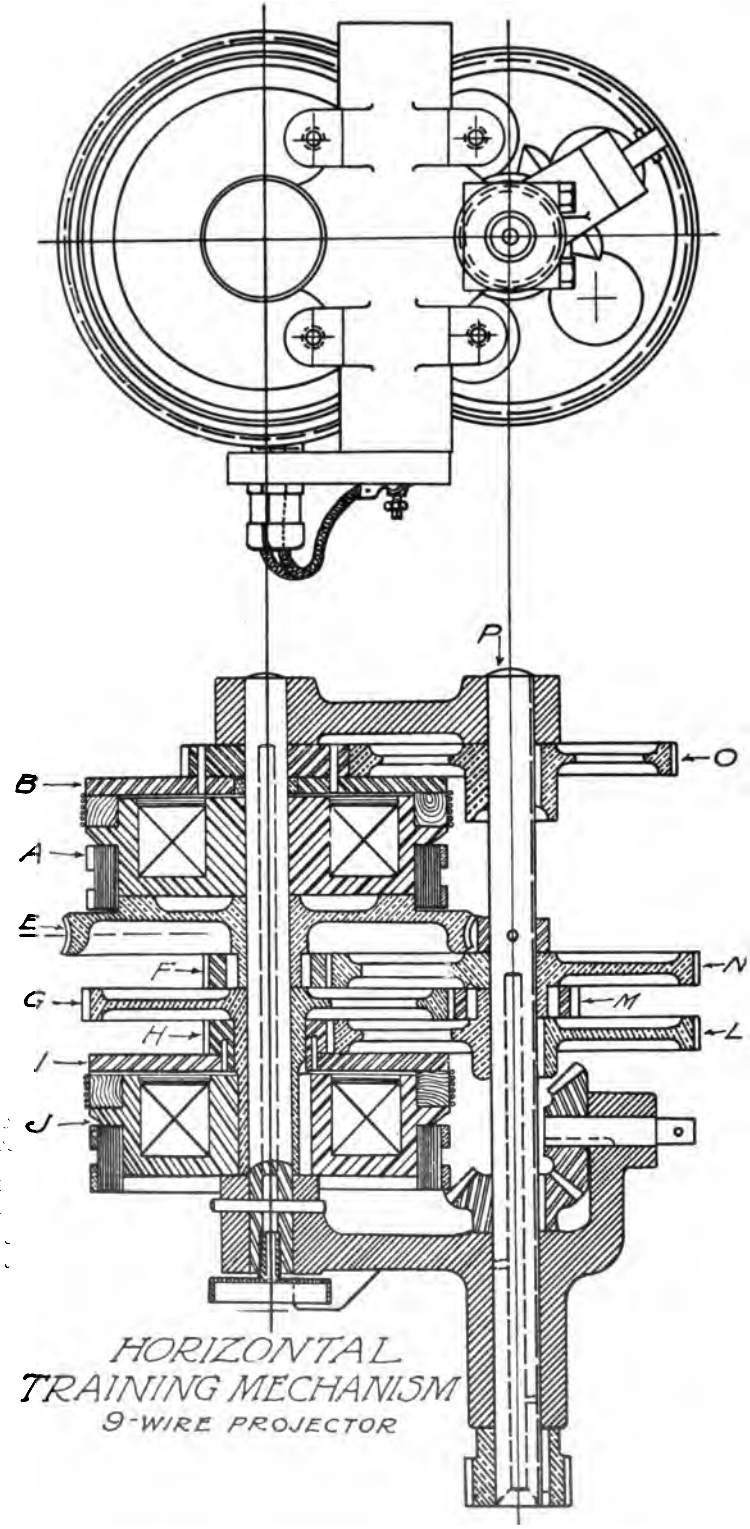
machine a series resistance is necessary; in this case .27 ohms is selected because it represents an average value for our installations. For the same reason, a 10 per cent. rise is given the compound generator characteristic.

A′ is the shunt machine's characteristic and A is the lamp characteristic. B and B′ represent the same for the compound machine. In each case, to obtain the points for the lamp characteristic, subtract from the generator characteristic the product of the current and the series resistance. In this diagram it is

assumed that the normal arc is 200 amperes and 65 volts, a Rosenberg generator characteristic being selected which meets these conditions, no series resistance being used, and is represented by R. To note the difference in the current regulation, we will assume the arc normal and then to change in resistance say from .32 ohms to .16 ohms. It may be noted that with the compound generator system the current would rise to 290 amperes, in the shunt 250 amperes and in Rosenberg 225 amperes. Evidently a shunt machine is better than a compound and a Rosenberg machine is better than either.

The property of the arc stream's resistance being a function of the current makes a condition of instability readily developed. Those who have operated a searchlight are familiar with how an arc will be burning quietly and, for no apparent reason, it will start and continue unstable for a half hour or so. A good current regulation would avoid such occurrence. Aside from steadiness in the beam there would be no such thing as the circuit-breaker going out. In fact, even the carbons getting stuck together would not throw the circuit breaker.

APPENDIX


P
O
B
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HORIZONTAL
TRAINING MECHANISM
9-WIRE PROJECTOR

Fig. 57.

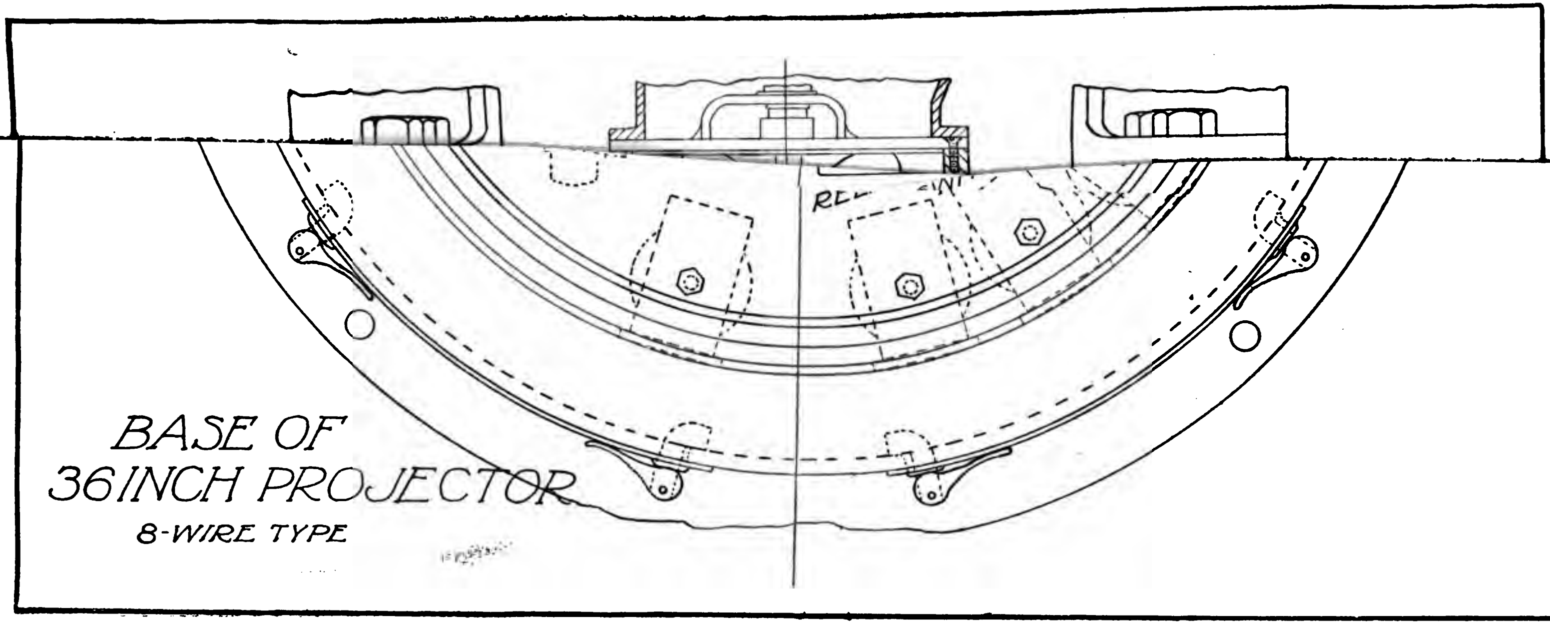

Fig. 58.